Texas A&M Engineering
TEEX
Extension Service

Infrastructure Training & Safety Institute

Basic Water Works Operations

TEXAS WATER TRAINING ACADEMY™

INSTRUCTOR GUIDE

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07/17

BASIC WATER WORKS OPERATIONS

INSTRUCTOR GUIDE

Texas A&M Engineering Extension Service (TEEX)

Infrastructure Training & Safety Institute (ITSI)

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Basic Water Works Operations

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Class Schedule

	Session	Module	Instructional Hours		
			Classroom	Lab/Field Activity	Total
Day 1	AM Session 1	Module 0: Course Introduction	30 min	0	30 min
		Module 1: Water Utility Operators	80 min	0	80 min
		Break	0	0	10 min
	AM Session 2	Module 2: Public Relations	60 min	0	60 min
		Module 3: Water Quality	60 min	0	60 min
		Lunch	0	0	0
	PM Session 1	Module 3 continued	60 min	0	60 min
		Module 4: Ground Water Production	50 min	0	50 min
		Break	0	0	10 min
	PM Session 2	Module 4 continued	120 min	0	120 min
Daily Totals			460 min	0 min	480 min

	Session	Module	Instructional Hours		
			Classroom	Lab/Field Activity	Total
Day 2	AM Session 1	Module 5: Surface Water Production	110 min	0	110 min
		Break	0	0	10 min
	AM Session 2	Module 5 continued	60 min	0	60 min
		Module 6: Disinfection	60 min	0	60 min
		Lunch	0	0	0
	PM Session 1	Module 6 continued	110 min	0	110 min
		Break	0	0	10 min
	PM Session 2	Module 7: Distribution	120 min	0	120 min
Daily Totals			460 min	0 min	480 min

	Session	Module	Instructional Hours		
			Classroom	Lab/Field Activity	Total
Day 3	AM Session 1	Module 8: Safety	80 min	0	80 min
		Break	0	0	10 min
	AM Session 2	Module 9: Calculations	110 min	0	110 min
		Course Review & Evaluation	40 min	0	40 min
Daily Totals			230 min	0 min	240 min

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Instructor Preparation Checklist

1. Off-site preparation
   - ☐ If taught at customer location, customer will supply all necessary equipment.
2. Equipment
   - ☐ Dry erase, chalk board, or SmartBoard (depending on classroom equipment)
3. Instructional aids/media
   - ☐Instructor guide (WWW001 IG)
   - ☐Computer with presentation slides for all modules
   - ☐Video/data projector
   - ☐Screen or monitor with speakers
   - ☐Miscellaneous extension, audio and video cables/cords
4. Participant material
   - ☐ Participant manual (WWW001 PM)
   - ☐ Participant registration forms
5. Participant evaluation material
   - ☐ TEEX Course Feedback Survey
6. Special requirements/instructions
   - ☐ Take along promotional material with information on other TEEX courses.
   - ☐ Check the roster in case a conflict has necessitated sending a replacement participant.
   - ☐ If participants are not listed on the roster, verify they are paid with the Customer Care Center (800-SAFE-811 or 800-723-3811).

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Module 0

Introduction and Orientation

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Instructional Guidance

Time

15 minutes

Materials/Equipment

1. Participant manual
2. Computer with presentation slides for module 0
3. Video/data projector
4. Screen or monitor
5. Course registration form

Instructor Preparation

Prepare projector and position first presentation slide.

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Introduction

Slides 1–2

In this module, the instructor will familiarize participants with the facility's safety and convenience features, the location of the facility's designated smoking area(s), and any additional resources or equipment available.

Participants will introduce themselves, complete registration procedures and receive course information, including prerequisites and attendance requirements, as well as evaluation and certification information. The instructor will conduct a brief overview of the course, which includes the goals and objectives, required participant equipment, and the class schedule.

About this Course

The Water and Wastewater Training Program is one of the four original programs established in 1940 as part of the Industrial Extension Service, which later became the Texas A&M Engineering Extension Service. Since that time, the program has been providing water and wastewater professionals with the required training for obtaining state required licenses in the water utilities industry.

The Water and Wastewater Program consists of training in water, wastewater, on-site sewage facilities, backflow prevention, and terrorism awareness and preparedness for water utilities. The program currently offers 44 different courses ranging from entry level to advanced level. The program also offers five different correspondence courses that allow participants to obtain required training at their own pace and from any location. The program currently has five "hands-on" mobile trailers that enhance the learning of the participants with real-life situations.

On average, the Water and Wastewater Program delivers over 650 courses per year to approximately 12,000 participants, with a total of 210,000 contact hours. The program provides a professional full-time staff consisting of a Training Manager and 8 instructors. In addition, the program utilizes numerous professional adjunct instructors.

Course Goal

Upon successful completion of this course, the participant will be able to apply proven methods for safety, production, treatment, distribution of potable water, and public relations.

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Target Audience

This course is designed for public works personnel and new employees of a water system.

Delivery Methods

Course delivery consists of instructor-led discussions, participant activities, and practical application.

Course Prerequisites

There are no prerequisites for this course.

Recommended Training

None

Course Length

20 hours

Certification Information

TEEX has been approved as an Authorized Provider by the International Association for Continuing Education and Training (IACET), 1760 Old Meadow Road, Suite 500, McLean, VA 22102.

In obtaining this approval, TEEX has demonstrated that it complies with the ANSI/IACET 1-2007 Standard which is widely recognized as the Standard of good practice internationally. As a result of their Authorized Provider membership status, TEEX is authorized to offer IACET CEUs for its programs that qualify under the ANSI/IACET 1-2007 Standard.

TEEX is authorized by International Association for Continuing Education and Training (IACET) to offer 2.0 CEUs for this program.

Registration/Attendance

In order to receive full credit for this course, attendance is crucial. All participants must complete a registration form at the beginning of the course, sign the attendance roster on the day of the course, and must complete the evaluation at the end of the course in order to receive a certificate of completion.

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Licensing Information

Participants will be issued 20 hours of water licensing credit by the Texas Commission on Environmental Quality (TCEQ) upon successful completion of this course.

Class Schedule

Day 1

Morning

Module 0: Introduction and Orientation

Module 1: Water Utilities Operators

Module 2: Public Relations

Module 3: Water Quality

Afternoon

Module 3 continued

Module 4: Groundwater Production

Day 2

Morning

Module 5: Surface Water Production

Module 6: Disinfection

Afternoon

Module 6 continued

Module 7: Distribution

Day 3

Morning

Module 8: Safety

Module 9: Calculations

Course Review and Evaluation

Participant Evaluation Strategy

The evaluation plan incorporates strategies for evaluating participants' progress in the classroom. The instructor will use oral and written module review questions and a final exam to assess participants' mastery of the material. Problem areas identified in the classroom will be reviewed in further detail.

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Summary

Now that the administrative section of the course is complete, you can turn your attention to Module 1, “Water Utility Operators.”

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Module 0 Presentation Slides

WWW001

Basic Water Works Operations

Module 0

Introduction and Orientation

Introduction

Safety
- Emergency evacuation
- CPR and first aid

Source: TEEX

Source: Shutterstock

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Introduction

Introductions
- Instructor
- Participants
  - Name
  - Position/job duties
  - Company/organization

Introduction

Facility orientation and logistics
- Lunch and breaks
- Coffee, vending machines
- Restrooms
- Smoking areas
- Laptops, cell phones, and pagers

Source: Shutterstock

About This Course

Course Goal:

Upon successful completion of this course, the participant will be able to apply proven methods for safety, public relations, production, treatment, and distribution of potable water.

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About This Course

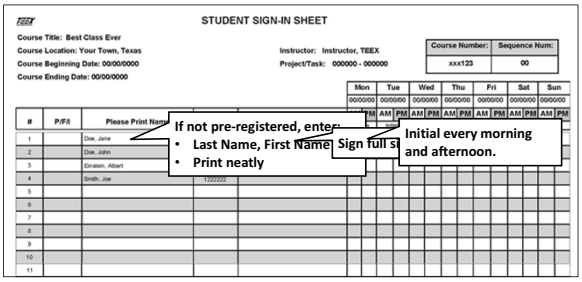
Registration

- Participant Verification Form (if pre-registered)
- Participant Information Form (if not pre-registered)

Source: TEEX

About This Course

Sign-In



About This Course

Attendance

- To receive full credit hours for course, 100% attendance is required.
- See instructor for emergency situations.

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About This Course

Schedule

- Day 1
  - Module 0: Introduction and Orientation
  - Module 1: Water Utility Operators
  - Module 2: Public Relations
  - Module 3: Water Quality
  - Module 4: Ground Water Production

About This Course

- Day 2
  - Module 5: Surface Water Production
  - Module 6: Disinfection
  - Module 7: Distribution

About This Course

- Day 3
  - Module 8: Safety
  - Module 9: Calculations
  - Course Review and Evaluation

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About This Course

Participant Evaluation

- Active involvement in course
  - Class discussion
  - Participant activities
- Course final exam

Next module

Module 1:
Water Utility Operators

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Module

1

Water Utility Operators

Terminal Objective

Upon the successful completion of this module, participants will be able to explain the responsibilities of a water utility operator.

Enabling Objectives

1. Discuss employment requirements for water utility employees.
2. Discuss the types of public water systems.
3. Discuss regulation of the water utility industry.

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Instructional Guidance

Time

1 hour 20 minutes

Materials/Equipment

1. Participant manual
2. Laptop with presentation slides for module 1
3. Internet connectivity
4. Video/data projector
5. Screen or monitor

Instructor Preparation

Prepare projector and position first presentation slide.

Application of Participants' Knowledge/Skills

Allow ample time for participants to complete the review questions at the end of this module.

Evaluation of Participants

Go over the review questions at the end of the module, answering any questions the participants may still have.

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Introduction

Slides 1–4

The water utility field touches everyone because water is essential to life and health. The production and delivery of safe drinking water to consumers is the primary purpose of the water utility industry.

> ***Instructor Note***
>
> *Review this module's objectives with participants so they are aware of what they will be learning during this module.*

Water Utility Personnel

Responsibilities of Water Utility Personnel

Standards

Slide 5

Those who work in, supervise, or manage a public water supply have a responsibility to meet federal and state standards:

- Water must be disinfected, safe to drink, and suitable for community use.
- Water must be delivered at adequate pressure without interruption.
- The supply must be ample in quantity.

> ***Instructor Note***
>
> *Water is essential to life, health.*
>
> *Definition: potable means safe to drink.*
>
> *Adequate pressure is 35 psi during normal operations, and at no time shall pressure fall below 20 psi at peak demands.*
>
> *Sufficient quantity means to supply enough water for all uses; including peak demands during emergencies, extreme conditions (fires, leaks, or other)*

Security

Employees should guard the water supply and facilities from contamination, vandalism, and even terrorism.

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Learning Check

1. What are the impacts if you do not secure your water facility?
   a. contaminate the water
   b. damage pumps and motors
   c. release hazardous chemicals

Some typical vulnerabilities of the water system include the following:

Slide 6

- Water production facilities
- Locked gates and pump rooms
- Storage tank hatchways
- Intruder resistance fencing

Slide 7

- Water distribution system
- Flush valves and fire hydrants
- Backflow prevention devices
- Wastewater collection systems

Learning Check

1. What vulnerabilities can you think of at your facility?
   a. hole in fence
   b. chlorine stored outside gate
   c. no visitor sign in required
2. How might the vulnerability be mitigated?
   a. fix fence
   b. move storage area
   c. sign-in at the office

Slide 8

Some security improvements that could be considered at your facility include the following:

- Check facility security.
- Check system pressure.
- Check system chlorine residual.
- Evaluate chlorine dosage.
- Check remote sewer manhole and cleanout locations.
- Go from condition yellow to condition orange.

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Each system should assess its risk of a security breach and coordinate reaction with local police. Report public health risks to the TCEQ, Public Drinking Water Homeland Security at 1-888-777-3186 or 1-512-239-4449.

Slide 9

Cost Control

Operators must provide economical service. They must do the best job they can at the lowest possible cost.

Public Relations

Public relations is another responsibility of the water utility operator. Remember that customers are entitled to courteous treatment and answers to questions about water. Public relations is discussed in greater detail in module 2.

Duties of the Water Utility Employee

Slide 10

- Repairing, flushing, and disinfecting water mains
- Collecting water samples and analyzing water samples for chlorine residuals
- Reading meters

Slide 11

- Operating and maintaining pumps, motors, and valves
- Operating and maintaining chlorinators and other equipment
- Operating and maintaining utility vehicles and trenching equipment
- Handling traffic control
- Maintaining accurate records
- Billing customers
- Managing the utility office

Instructor Note

Facilitate a discussion on some of the tasks water operators may do in addition to those assigned to them as water operators. This is a chance for participants to share their experiences.

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Recordkeeping

Slide 12

Table 1.1 provides a summary of recordkeeping requirements for bacteriological, chemical, and consumer confidence reports.

Table 1.1: Required Recordkeeping*

Type of Record	Retention/Reporting Time
Bacteriological analysis	5 years
Chemical analysis	10 years
Action taken to correct violations of primary drinking water regulations	3 years after last action taken with respect to particular violation involved
Written reports, summaries, or communications relating to sanitary surveys conducted by system, consultant, or the commission	10 years after completion of the survey involved
Variance or exemption granted	5 years following the expiration of such variance or exemption
Results of tests, measurements, or analysis required by the Drinking Water Standards	Must be reported within 10 days following test, measurement, or analysis
Consumer Confidence Reports (EPA required)	A copy of each for 5 years
*** Title 30 Texas Administrative Code 290.46 (30 TAC 290.46)**	

Operator Licensing

The Texas Commission on Environmental Quality (TCEQ) administers water operator licensing. All public water systems are required to employ licensed operators even if the system only redistributes treated water bought from another source. See licensing requirements in Appendix C.

Licensing Requirements of Texas Operators

Slide 13

Texas water operators must:

- produce safe water at all times;
- collect and submit monthly bacteriological samples; and
- keep records and compile monthly reports.

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Public Water Systems

Slide 14

A public water system:

- provides the public with piped water for human consumption;
- serves at least 15 service connections; and
- regularly serves at least 25 individuals daily for at least 60 days out of the year.

Public water systems include cities, municipal utility districts (MUD), rural water supply corporations, mobile home parks, and campgrounds.

A public water system is either a "community" water system or "non-community" water system.

Community Water Systems

A community water system is described as follows:

A public water system that has a potential to serve at least 15 service connections on a year-round basis or serves at least 25 individuals on a year-round basis. Service connections shall be counted as one for each single-family residential unit or each commercial or industrial establishment to which drinking water is supplied from the system (30 TAC Chapter 290).

Examples of community water systems:

- Municipalities
- Municipal utility districts
- Rural water supply corporations
- Mobile home parks
- Housing development

Non-Community Water Systems

A non-community water system is any public water system that is not a community system. There are three types of non-community water systems: Transient, Non-transient, and Seasonal. Examples of non-community water systems:

- Travel trailer spaces
- Hotel and motel rooms
- Service stations
- Restaurants

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Transient Non-Community Water System—A public water system that is not a community water system and serves at least 25 persons at least 60 days out of the year, yet by its characteristics, does not meet the definition of a non-transient non-community water system. Examples of transient non-community water systems are RV parks, hotel and motel rooms, service stations/convenience stores and restaurants.

Non-Transient Non-Community Water System—A public water system that is not a community water system and regularly serves at least 25 of the same persons at least six months out of the year. Examples of non-community non-transient water systems are oil and petrochemical plants, and industrial facilities such as paper mills.

Seasonal public water system—A non-community public water system that is not operated as a public water system on a year-round basis and starts up and shuts down at the beginning and end of each operating season.

Regulation of the Water Utility Industry

A number of national, state, and local agencies regulate the water utility industry.

National

Federal agencies impacting the water utility industry:

- U.S. Environmental Protection Agency (EPA) – Regulates water quality through the Federal Safe Drinking Water Act and control of underground injection of wastes and solid waste management
- U.S. Army Corps of Engineers – Provides flood protection, dam safety, and planning and construction of reservoirs
- U.S. Department of the Interior – U.S. Geological Survey conducts water studies
- U.S. Fish and Wildlife Service – Administers programs of conservation, development, and management
- Farmers Home Administration – Makes grants and loans to rural water supply corporations

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Following are some federal laws that impact the water utility industry:

Slide 15

- Safe Drinking Water Act of 1974 (PL93-523) – This is the most important federal law and establishes four uniform national safety and quality standards for drinking water, including physical, chemical, bacteriological, and radiological characteristics.
- Federal Water Pollution Control Act of 1972 – Provides for restoring and maintaining the chemical, physical, and biological quality of water sources

State

Slide 16

The state agency that regulates public water supplies in Texas is the Texas Commission on Environmental Quality (TCEQ).

The TCEQ establishes drinking water standards, reviews plans for construction of drinking water projects, administers the federal Safe Drinking Water Act, administers licensing for water utility personnel, conducts annual sanitary surveys on public drinking water systems, and administers the Texas Water Pollution Control program and Air Quality program.

Slide 17

Water system utility personnel are required to notify the TCEQ of any of the following:

- Changes in water source
- Change or alteration of the system
- Alteration or addition to the treatment facility
- A new system or facility to be built
- Changes in water quality
- Water supply health hazards

Before starting construction, the water utility must submit engineering plans to the TCEQ for approval.

To contact the TCEQ about an emergency after hours, call the nearest regional office and follow the after-hour instructions. If after-hour contact is not available, call the following:

The 24-hour emergency response number in Austin is 512-463-7727.

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Regional and Local

Slide 18

Following are some regional and local agencies impacting the water utility industry in Texas:

- Municipal utility districts
- Rural water supply corporations
- Investor-owned public water supply systems
- Drainage districts
- River authorities
- Groundwater conservation districts
- Subsidence districts

Summary

Slide 19

What you do is more than just a job. You are responsible for providing a product to the citizens of Texas that they consume directly. Because of that fact, you must provide water that is safe to drink; anything less could be disastrous.

In this module, you have learned about the responsibilities and duties of water utility personnel, including meeting state and federal standards for a public water supply and maintaining accurate records. You have also learned about the training and licensing requirements for water utility personnel. In addition, you should now be able to describe the difference between community and non-community water systems, and identify the national, state, and local regulations of a water utility industry.

In the next module, you will learn about the role that the water utility system employee plays in establishing good public relations.

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Module 1 Review Questions

1. Operators have a responsibility to provide drinking water that meets federal and state standards.

   a. **true**

   b. false

2. Water must be disinfected, delivered at **inadequate** pressure, and be ample in quantity.

   a. true

   b. **false**

3. Utility employees should guard the water supply and facilities from contamination, **public tours,** and even terrorism.

   a. true

   b. **false**

4. The state requires bacteriological sample results be kept **two** years.

   a. true

   b. **false**

5. The state requires chemical analysis be kept at least 10 years.

   a. **true**

   b. false

6. EPA requires a water system to keep a copy of each consumer confidence report at least five years.

   a. **true**

   b. false

7. A public water system provides the public with piped water for human consumption, serves at least 15 service connections, and regularly serves at least 25 individuals daily at least 60 days out of the year.

   a. **true**

   b. false

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8. The water utility field affects everyone because _____.

   a. water is used for recreation

   b. water is used for agriculture

   c. water is used for industry

   d. **water is essential to life and health**

9. The water utility employee should remember customers are entitled to _____.

   a. courteous treatment

   b. abuse public servants

   c. always be right

   d. answers to questions about water

   e. **a and d**

10. In Texas, water operator licensing is administered by the _____.

    a. EPA

    b. **TCEQ**

    c. TEEX

    d. OSHA

11. All public water systems are required to employ licensed operators even if the system only _____ treated water bought from another source.

    a. chlorinates

    b. sells

    c. **redistributes**

    d. stores

12. Public water systems include cities, municipal utility districts, rural water supply corporations, mobile home parks, and _____.

    a. private wells

    b. **campgrounds**

    c. public pools

    d. public lakes

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13. Examples of community water systems include _____.

    a. municipalities

    b. municipal utility districts

    c. rural water supply corporations

    d. mobile home parks

    e. **All the above**

14. A federal agency impacting the water utility industry is the _____.

    a. TCEQ

    b. **EPA**

    c. TEEX

    d. OSHA

15. The most important federal law impacting the water utility industry is the _____.

    a. Water Resources Development Act

    b. Federal Water Pollution Control Act

    c. Hazard Communication Act

    d. **Safe Drinking Water Act (PL93-523)**

16. The four national safety and quality standards for drinking water covered in the Safe Drinking Water Act are physical, chemical, _____, and radiological.

    a. mineral

    b. thermal

    c. **bacteriological**

    d. mathematical

17. The state agency that regulates drinking water in Texas and administers the federal Safe Drinking Water Act is the _____.

    a. **TCEQ**

    b. DPS

    c. PUC

    d. TDH

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18. Water utility system personnel are required to notify the TCEQ of changes or alterations of the system, a new facility to be built, and water supply _____.

    a. rate increases

    b. **health hazards**

    c. bond elections

    d. bid proposals

19. Some regional and local agencies impacting the water utility industry are municipal utility districts, rural water supply corporations, drainage districts, _____, groundwater conservation districts, and subsidence districts.

    a. school districts

    b. postal districts

    c. real estate agencies

    d. **river authorities**

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Module 1 Presentation Slides

Basic Water Operations

Module 1
Water Utility Operator

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Terminal Objective

Upon successful completion of this module, the participant will be able to explain the responsibilities of a water utility operator.

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Enabling Objectives

- Discuss employment requirements for water utility employees.
- Discuss the types of public water systems.
- Discuss regulation of the water utility industry.

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Water

- Essential to life and health
- 35 psi is adequate pressure
- Must not fall below 20 psi at peak
- Sufficient quantity

Responsibilities of Water Utility Personnel

- Maintain standard
  - Disinfected
  - Adequate pressure
  - Ample supply
- Provide security
  - Prevent contamination
  - Prevent vandalism/terrorism

Typical System Vulnerabilities

- Water production facility
- Locked gates/pump rooms
- Storage tank hatchways
- Intruder resistant fencing

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Typical System Vulnerabilities

- Water distribution system
- Flush valves and fire hydrants
- Backflow prevention devices
- Wastewater collection system

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Security Improvements

- Check facility security
- Check system pressure
- Check system chlorine residual
- Elevate chlorine dosage
- Check remote manholes and cleanouts
- Report health risks

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Other Security Concerns

- Cost control
  - Do the best job at the lowest cost
- Public relations
  - Customers deserve courteous service
  - Customers require answers concerning the water

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Duties of Water Utility Personnel

- Repair/flush water mains
- Disinfect produced water
- Take water samples
- Read water meters

Duties of Water Utility Personnel

- Operation/maintenance of pumps
- Operation/maintenance of chlorination facilities
- Billing the customer
- Keeping records

Required Record Keeping (30 TAC 290.112)

Type of Records	Retention Requirements
Bacteriological Analysis	5 years
Chemical Analysis	10 years
Corrective Actions	3 years
Written Reports	10 years
Variance or Exemption	5 years
Consumer Confidence Reports	5 years

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Operator Licensing Requirements

- Produce safe water at all times
- Collect, submit bacteriological samples
- Keep records
- Compile monthly reports
- Obtain continuing education credit hours
- Licensing through TCEQ (Appendix B)

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Public Water System

- Provides piped water for human consumption
- Serves at least 15 connections
- Serves at least 25 customers year-round
- Community water system
- Non-community water system

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National Regulations

- Safe Drinking Water Act of 1974
  - Uniform safety, quality standards
  - Physical, chemical, bacteriological, radiological characteristics
- Federal Water Pollution Control Act of 1972
  - Restoring, maintaining water sources
  - Chemical, physical, biological quality

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State Regulations

- Texas Commission on Environmental Quality (TCEQ)
  - Promulgate, enforce state laws
  - Enforce federal laws at the state level

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When To Notify TCEQ

- Change, alteration to the system
- Alteration, addition to treatment facility
- New system facility to be built
- Water supply health hazards (most important)

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Regional and Local Agencies

- Municipal utility districts
- Rural water supply corporations
- Investor-owned public water systems
- Drainage districts
- River authorities
- Groundwater conservation districts

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Module 1

Review Questions

End of Module 1

Next Module:
Public Relations

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Module 2

Public Relations

Terminal Objective

Upon the successful completion of this module, the participant will be able to describe how a water employee can demonstrate good public relations.

Enabling Objectives

1. Explain the importance of public relations.
2. List the water utility jobs impacting public relations.
3. Review ways of maintaining a positive public image.

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Instructional Guidance

Time

1 hour

Materials/Equipment

1. Participant manual
2. Laptop with presentation slides for module 2
3. Internet connectivity
4. Video/data projector
5. Screen or monitor

Instructor Preparation

Prepare projector and position first presentation slide.

Application of Participants' Knowledge/Skills

Ask participants to complete the review questions at the end of the module and allow them ample time.

Evaluation of Participants

Go over the review questions at the end of the module, answering any questions the participants may still have.

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Introduction

Slides 1-4

Public relations is vital for the growth of all industries. The relationship between the customer and the provider must be a positive one in order to provide the best possible service. In this module we will discuss the components of positive public relations.

Building Good Customer Relations

Definition

Public relations (PR) is the relationship between YOU, the water utility employee, and the customer.

This relationship is based on the quality of service and the degree of consideration the customer receives. Never take your customers for granted!

Learning Check

1. Who are your customers?

   a. public

   b. visitors to the community

   c. other employees

The Keys to Good Public Relations

Slide 5

Remember that everything the utility does is a matter of public relations. Customers are entitled to courteous treatment and deserve explanations about their drinking water and service.

Every employee is a PR person. Meter readers, operators, construction people, billing clerks, and all others who work for the water utility meet customers at one time or another. The interaction the public has with utility personnel makes an impression in the public mind, good or bad.

Water Utility Jobs Impacting Public Relations

Slide 6

Each of the following water utility positions involves interaction with the public. The sections that follow describe how to use these interactions to create a positive experience.

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Meter Readers

Meter readers are the persons with whom customers have the most frequent contact. As far as most people are concerned, meter readers ARE the utility. Meter readers can often remind customers of their water bill. For this reason, they are the employees most likely to hear complaints about water rates, service, and system policies.

Meter readers can be ambassadors of goodwill by practicing the following:

- Wear identifying clothing.
- Be neat and courteous.
- Show customers how to read their meter.
- Explain utility policies such as delinquent notices or disputed readings.
- Do not trample flowerbeds, damage fences, mistreat pets, or create an undue inconvenience for the customer.

Maintenance and Repair Crews

Slide 6

Maintenance crews are the next most visible water system employees. Actions that maintenance crews should take to show positive public relations include the following:

- Observe personal neatness on the job.
- Be courteous drivers.
- Avoid taking naps in the truck.
- Warn customers of service interruptions.
- Provide signs and barriers to protect the public.
- Keep the area clean and replace fences and repair landscaping according to utility policy.

The Plant Operator

The plant operator is responsible for treating the water to assure it is safe to drink and use, thereby protecting customer health and welfare. However, the operator may have little contact with customers. Nevertheless, he or she has a part to play in building good public relations. The operator should be neat and courteous and trained to answer technical questions. For small systems, the operator is likely to be meter reader, repair crew, and pump operator.

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Other Employees

Slide 6

Other employees have opportunities to build customer goodwill:

- The office clerk should be courteous and helpful to both customers opening new accounts and existing customers.
- Dispatchers should handle complaints tactfully and in a timely manner.
- The custodian should take pride in maintaining clean and attractive facilities.

Learning Check

1. How do you build your customer relations?

   a. Give tours to elementary children.

   b. Host poster/essay contests during Water Awareness Week.

   c. If you tear up a yard, fix it back.

Maintaining a Good Public Image

Billing

Slide 7

Billing is an opportunity to address good public relations:

- Assure water bills are accurate, itemized, neat, and legible.
- Mail bills at the same time every month so customers can budget accordingly.
- Enclose "stuffers"—departments to call for utility service, explanations of utility policy, a history of the utility, or tips on water conservation.
- Delinquent notices can be managed in a tactful and tasteful way. They should be mailed in an envelope and the message does not have to be accusing or irritating. The wording should be businesslike and the disconnection/reconnection procedure clear.

Consumer Confidence Reports

Slide 7

By authority of the 1996 Safe Drinking Water Act, EPA requires community water systems to provide customers with a yearly report on the system's water quality. If these reports are attractive and easy to understand they can build goodwill and trust with the customer.

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Employee Relations

Employees who receive fair treatment in wages, benefits, and safe working conditions will be public relations assets. It is important that the utility have a sense of pride and professionalism. All employees should be kept informed of utility plans and policies.

Learning Check

1. Fill out the professional scorecard (Figure 2.1) and rank yourself.
2. How can you improve your score?

   a. Join trade association.

   b. Visit other utilities.

   c. Work on upgrading license.

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My Professional Scorecard

Rank Yourself:

0 = I do not do this 5 = Sometimes I do this 10 = I do this all the time

____ 1. I am knowledgeable of my company's policies.

____ 2. I maintain a neat appearance throughout the day.

____ 3. I read and study during non-working hours.

____ 4. I train new employees.

____ 5. I plan on upgrading my license.

____ 6. I subscribe to at least one trade publication.

____ 7. I am an active member of a state trade association.

____ 8. I am a member of a national trade association.

____ 9. I visit other utilities to gain another perspective.

____ 10. I have a personal goal for advancement in the water utilities field.

____ **Total**

Add Your Score:

100 = You are a true professional

90 = You are almost there

80 = Only a little further to go

70 = Keep at it – you'll make it

60 = Try harder

50 = You are half way to the top

Figure 2.1: Professional scorecard. *Source: TEEX.*

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Complaints

Slide 9

All complaints should be treated as legitimate and investigated as soon as possible. If the person with the complaint is loud and abusive, you should not reply in kind. Instead, show concern, listen carefully and calmly, and offer to look into the complaint.

Assure you understand the problem, then make every effort to give the customer an answer in nontechnical language. If you don't know the answer, refer the customer to the proper person.

Follow up with a phone call, postcard, or an email to make sure everything is satisfactory.

A complaint form ensures each problem is investigated and resolved (Figure 2.2).

COMPLAINT FORM

AREA: DATE:

NAME: _____ Taken by: _____ Treatment Plant #1 _____
ADDRESS: _____ Treatment Plant #2 _____
_____ Central Office _____
TELEPHONE: _____

COMPLAINT _____Taste _____Turbidity _____Low Pressure _____ High Pressure
_____ Odor _____Organisms _____ Noise _____ No Water
_____ Color _____ Other _____

INVESTIGATION—CAUSE _____ Emergency _____ Pump Failure _____ Regulator Failure
_____ Water Surge _____ Dead-end Main _____ Line Stoppage
_____ Water Outage _____ Power Outage _____ Other _____
Explanation _____

ACTION TAKEN _____ No Action Required _____ Under Investigation
_____ Main Flushed _____ Equipment Repaired
_____ Planned Shutdown _____ Customer to Correct
_____ Other _____
Explanation _____

ADDITIONAL INFORMATION _____
INVESTIGATION _____ DATE _____

Figure 2.2: Complaint form. *Source: TEEX.*

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Grounds and Facilities

Slide 9

The proper maintenance and appearance of pump stations, storage tanks, treatment plants, and grounds indicates to the public your professional attitude. If facilities are dirty, run-down, in need of painting, or overgrown with weeds, you will be unable to convince the public you are doing a good job!

If your utility has a poor image, the public may not support bond issues or rate increases. The public can even lose confidence in the quality of their water.

Water utility personnel must do their best to provide quality water and service to the customers who are paying for it.

Public Relations Summary and Review

Slide 10

- Perform preventive maintenance so that service does not go out of order.
- Accept routine requests with enthusiasm, as though they are as important to the utility as they are to the customer.
- Listen willingly to special requests and seek solutions to oblige the customer within utility policy.
- Listen sympathetically to complaints. If the utility is at fault, correct the problem in a timely manner. If the customer is mistaken, handle the situation tactfully.
- Schedule appointments for installation and repair at the convenience of the customer whenever possible.
- Treat customers as though another water utility across the street is competing for your customers.
- Be certain you understand what you are doing. Take pride in your work and appearance, be courteous, and show respect for others and their property.

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Summary

Slide 11

Whatever you do is seen directly or indirectly by the public and it is your responsibility to be professional. You must strive to maintain a good image with the public. Public relations is something that is not very often thought of as a requirement for water utility operators, but you must exude good public relations constantly.

In this module, you have learned how the interactions of water utility personnel with the public can impact public relations. In addition, you have learned that a neat and professional appearance is equally important to creating a positive public relations experience.

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Module 2 Review Questions

1. Public relations (PR) is the relationship between YOU, the water utility employee, and the **mayor**.

   a. true

   b. **false**

2. The keys to good customer relations are (1) everything the utility does is PR, (2) customers are entitled to courteous treatment, (3) every employee is a PR person.

   a. **true**

   b. false

3. Meter readers are the persons with whom customers have the **least** contact.

   a. true

   b. **false**

4. Meter readers can be ambassadors of goodwill.

   a. **true**

   b. false

5. Maintenance crews can warn customers of service interruptions and provide signs and barriers to protect the public.

   a. **true**

   b. false

6. The plant operator is responsible for treating the water to assure it is safe to drink and use.

   a. **true**

   b. false

7. Water bills should be accurate, itemized, and neat, and payment should be **optional**.

   a. true

   b. **false**

8. It is **not** important that the utility have a sense of pride and professionalism.

   a. true

   b. **false**

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9. All employees should be kept informed of utility plans and policies.

   a. **true**

   b. false

10. Complaints should be treated as **"griping"** and investigated as a **last priority**.

    a. true

    b. **false**

11. In small water systems the operator is often _____.

    a. **meter reader, repair crew, and pump operator**

    b. the highest paid employee

    c. a college graduate

    d. all listed

12. "Stuffers" sent to customers in billing statements may contain _____.

    a. departments to call for service

    b. explanations of utility policy

    c. a history of the utility

    d. tips on water conservation

    e. **all the above**

13. Delinquent payment notices should be _____.

    a. tactful and tasteful

    b. mailed in an envelope

    c. businesslike

    d. **all listed**

14. EPA requires community water systems to provide customers with a _____ report on the system's water quality.

    a. weekly

    b. monthly

    c. **yearly**

    d. none listed

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15. If these reports are attractive and easy to _____, they can build goodwill and trust with the customer.

    a. misinterpret

    b. misconstrue

    c. misunderstand

    d. **understand**

16. Good treatment of employees includes fair wages, benefits, and _____ working conditions.

    a. tense

    b. **safe**

    c. hazardous

    d. insecure

17. Follow up with a phone call or _____ to make sure everything is satisfactory.

    a. postcard

    b. email

    c. letter

    d. **a and b**

18. Water plant facilities should be kept neat and clean to _____.

    a. indicate your professional attitude

    b. keep public support

    c. keep confidence in the water quality

    d. **all listed**

19. Listen to special requests and seek solutions to oblige the customer within _____.

    a. **utility policy**

    b. five working days

    c. tradition

    d. secrecy

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20. Treat customers as though another water utility across the street is competing for your _____.

    a. job

    b. employees

    c. **customers**

    d. revenue

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Module 2 Presentation Slides

Basic Water Operations

Module 2
Public Relations

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Terminal Objective

Upon successful completion of this module, the participant will be able to describe how a water employee can demonstrate good public relations.

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Enabling Objectives

- Discuss the importance of public relations.
- List the water utility jobs impacting public relations.
- Review ways of maintaining a positive public image.

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Building Good Customer Relations

- Relationship between you and the customer
- Based on quality of service
- Based on degree of consideration
- Customer must not be taken for granted

Keys To Remember

- Everything utility does, matter of public relations
- Courteous treatment
- Explanations about water, service
- Every employee a PR person
- Utility's interaction leaves impression

Jobs Impacting Public Relations

- Meter readers
- Maintenance, repair crews
- Plant operators
- Office clerk
- Dispatchers
- Custodians

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Maintaining Good Public Relations

- Billing
- Consumer confidence reports (SDWA 1996)
  - Annual water quality report required by EPA
  - Builds goodwill and trust
- Employee relations

Professional Scorecard

- Complete the professional scorecard.
- How can you improve your score?

My Professional Scorecard

Rank Yourself:
0 = I do not do this 5 = Sometimes I do this 10 = I do this all the time
___1. I am knowledgeable of my company's policies.
___2. I maintain a neat appearance throughout the day.
___3. I read and study during non-working hours.
___4. I train new employees.
___5. I plan on upgrading my license.
___6. I subscribe to at least one trade publication.
___7. I am an active member of a state trade association.
___8. I am a member of a national trade association.
___9. I visit other utilities to gain another perspective.
___10. I have a personal goal for advancement in the water utilities field.
___Total

Add Your Score:
100 = You are a true professional
90 = You are almost there
80 = Only a little further to go
70 = Keep at it – you'll make it
60 = Try harder
50 = You are half way to the top

Maintaining Good Public Relations

- Handling complaints
  - Investigate promptly
  - Show concern
  - Provide answers in nontechnical language
  - Follow up with customer
- Maintain grounds and facilities

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Public Relations Review

- Perform preventative maintenance
- Accept requests enthusiastically
- Listen
- Schedule appointments conveniently
- Treat customers as a competitor would
- Take pride in your work

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Module 2

Review Questions

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End of Module 2

Next Module: Water Quality

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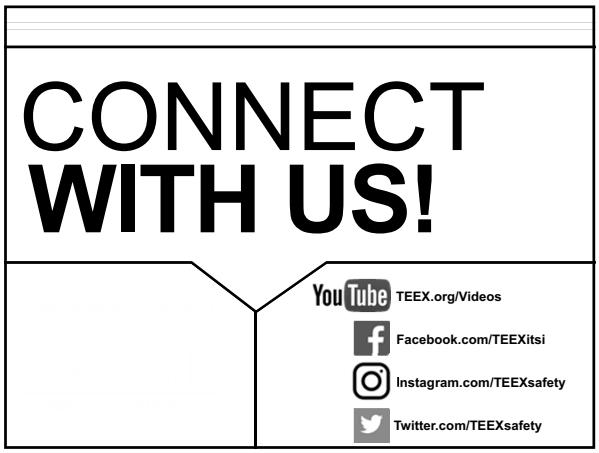

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Module 3

Water Quality

Terminal Objective

Upon the successful completion of this module, the participant will be able to describe the attributes of water from various sources.

Enabling Objectives

1. Explain the hydrologic cycle.
2. List the various uses of water.
3. Describe the preparation of water for public use.
4. Describe the physical characteristics, including the sources, of water.
5. Explain water quality standards.

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Instructional Guidance

Time

2 hours

Materials/Equipment

1. Participant manual
2. Laptop with presentation slides for module 3
3. Internet connectivity
4. Video/data projector
5. Screen or monitor

Instructor Preparation

Prepare projector and position first presentation slide.

Application of Participants' Knowledge/Skills

Ask participants to complete the review questions at the end of the module and allow them ample time.

Evaluation of Participants

Go over the review questions at the end of the module, answering any questions the participants may still have.

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Introduction

Slides 1-4

Three-fourths of the earth's surface is water, but only a small portion is available for the public water supply.

Of the earth's fresh water, about 75% is frozen in the polar ice caps. About 25% is under ground, where only a small portion can be tapped by wells. About 1/3 of 1% of fresh water occurs in lakes and rivers and about 20% of that is found in the Great Lakes.

Slide 5

Water is composed of two atoms of hydrogen and one atom of oxygen, represented by the molecular formula H_2O.

Water may be found in the following three states:

- Solid (ice). Water freezes at a temperature of 32° Fahrenheit (0° Celsius).
- Liquid (water). One gallon of fresh water weighs 8.34 pounds.
- Water vapor (gas, steam). Water boils at 212° Fahrenheit (100° Celsius), generating steam.

The concept that water is life is supported in the following facts:

- The human body is approximately 70% water.
- Water makes up approximately 83% of the blood.
- Water helps digest food and transport body waste.
- Water lubricates our joints and regulates body temperature.

Hydrologic Cycle

Slide 6

Water on the earth has been here since the beginning of time and it moves in a cycle between the earth and the atmosphere. This recycling process is called the hydrologic cycle (Figure 3.1).

> ***Instructor Note***
>
> *Go through the cycle using Figure 3.1.*

Water vapor rises from oceans, rivers, lakes, and the ground into the air, a process called evaporation. Sublimation is the process where ice and snow evaporate into the atmosphere without first melting into a liquid form. Water vapor is released from plant life in a process called transpiration.

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Slide 6

The water vapor is carried upward by rising currents of warm air to form clouds. When the vapor reaches cooler air high in the atmosphere, it condenses into rain, sleet, snow, or hail, which is called precipitation.

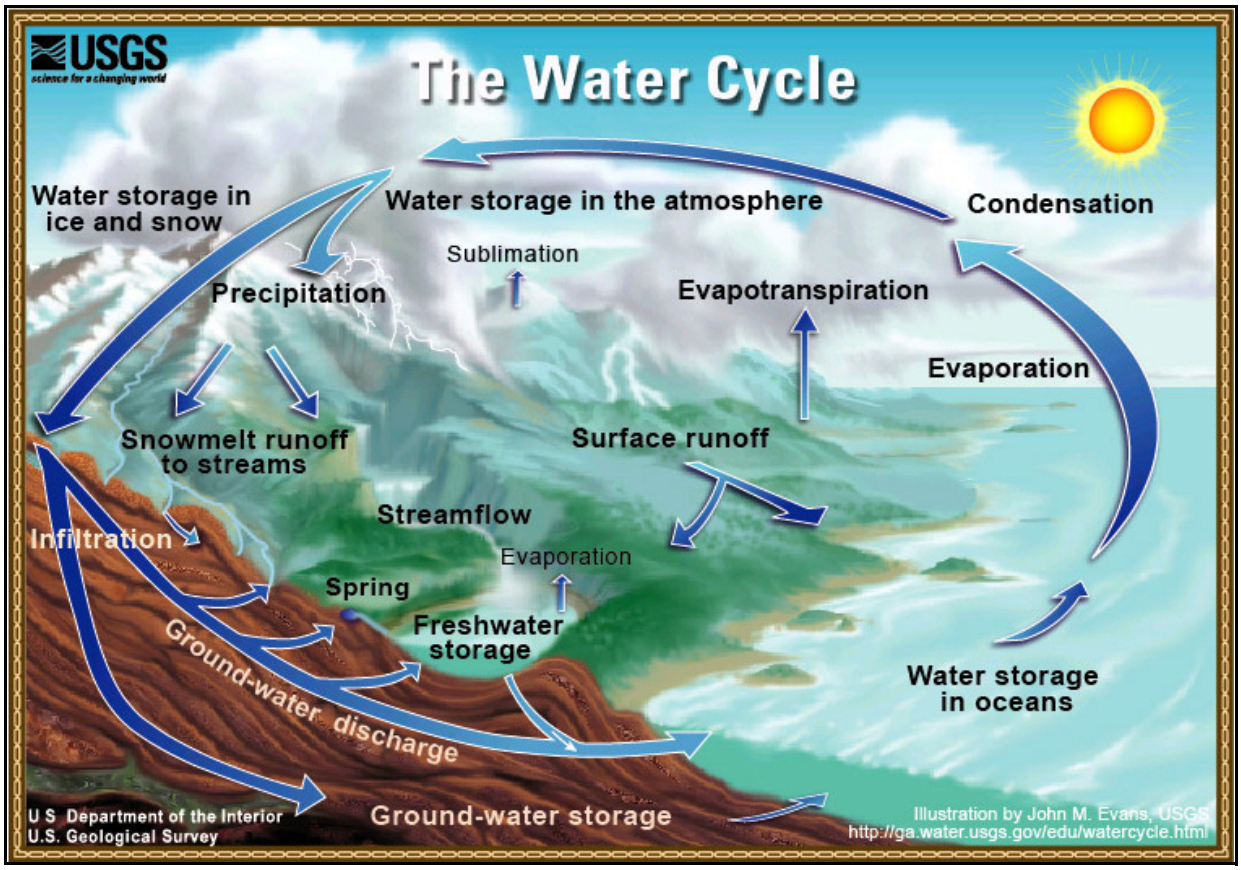

Figure 3.1: The hydrologic cycle. *Source: USGS*.

When precipitation reaches the earth, it soaks into the ground, which is called infiltration. The water is then available for plants. If the water continues to infiltrate farther and reaches the water table, recharging the groundwater supply in a process called percolation, it may run off into rivers and streams, then into lakes and oceans.

Pure water is never found in this natural cycle. Impurities in water are caused by materials that dissolve into it.

Uses of Water

Water is Life

Next to the air we breathe, water is our most vital need! All living things require water. Humans can live longer without food than without water.

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The human body is about 70% water. Water makes up 83% of the blood. Water helps digest food and transports body waste. Water lubricates our joints and regulates body temperature.

Domestic Use

Slide 7

Domestic use includes drinking, sanitation, and lawn watering. Contaminated water is most dangerous when utilized for drinking. Water quality standards, for all public water supplies, are based on the use of drinking.

Public Use

Public use includes recreation such as swimming, boating, and fishing. One of the most important purposes of a public water supply is fire protection. In Texas, to receive minimum recognition for firefighting capability under rate schedules adopted by the Texas Department of Insurance, a water system must be able to supply, at a fire's location, at least 250 gallons per minute (gpm) for two hours during peak demand.

Business Use

Business use includes industrial, commercial, and agricultural purposes. Commercial customers may require higher water demands for air conditioning, sanitation, or product processes. Water for agricultural use usually does not come from a public supply, but is obtained near the site where it is used.

Throughout the United States, billions of gallons of water are treated and distributed to the customer daily for domestic purposes alone. In many communities, water and wastewater facilities are the largest investment. Yet, water costs only a few dollars per 1,000 gallons. Because this business is carried on quietly, economically, and dependably, most customers take little notice of it until service is interrupted.

Definitions

Slide 8

Average usage in a community depends on temperature, rainfall, water cost, amount of supply, and the economic level of the community. Customers in a hot, dry climate or wealthy neighborhoods tend to use more water.

System design engineers use a rule of thumb of 130 gallons per person per day when more accurate data is not available. The TCEQ (30 TAC Chapter 290.45) requires community water systems to have a minimum production capacity of 0.6 gpm per connection at peak demand. Increased production capacity is required if a normal operating

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pressure of 35 pounds per square inch (psi) cannot be maintained throughout the system, or if a minimum of 20 psi cannot be maintained during firefighting, line flushing, etc.

Maximum usage is the amount of water used at peak demand or during drought. This amount is important in planning treatment plants, pumping equipment, storage, and distribution systems.

Minimum usage usually occurs during winter months or periods of heavy rainfall. Minimum usage must be considered when establishing water rates and selecting pumping equipment.

Instructor Note

- *Regulatory requirements (290.45)*
  - ***130 gallons per person per day***
  - ***0.6 gpm per connection***
  - ***20 psi minimum/35 psi normal***
- *How much water to produce?*

Water Supply

Production

Slide 9

Water for public use comes from one of two sources: groundwater or surface water. Groundwater is located beneath the earth's surface in water-bearing formations and is tapped by wells. Surface water is found in rivers, lakes, and reservoirs. Both of these natural sources of water are becoming scarce according to the TCEQ and other agencies. Therefore, treated salt water or wastewater is sometimes used for public supply.

Treatment

Slide 10

Prior to treatment, water is called raw water. The quality of water varies greatly. In order for a public water supply to be safe, clear, good tasting, odorless, noncorrosive, and reasonably soft, it must be treated.

Matter found in water may be organic or inorganic. The word “organic” comes from the word “organism.” Before scientists understood how to produce carbon compounds, only organisms (plants, animals, and humans) could produce them. At that time, organic matter was only living or once-living organisms, or matter produced by organisms. Sugar, paper, and leather are examples of organic matter produced by organisms.

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Today, organic matter is defined as any compound that is primarily carbon based and contains hydrogen. Organic matter can be natural, such as sugar, or synthetic, such as plastic. Inorganic matter is not primarily carbon based, but may contain hydrogen. Sand, rock, metals, and minerals are examples of inorganic materials.

One of the purposes of water treatment is to reduce or neutralize harmful levels of organic and inorganic matter.

The most important treatment of water is disinfection, which destroys disease-causing microorganisms.

Water must be treated for turbidity—suspended particles in the water.

Other treatment processes are used to remove taste, odors, and color.

Water that is corrosive, scale producing, or staining must be treated.

A public water supply must deliver potable water to its customers. Potable means the water is free of disease-causing organisms, has a chlorine residual, and is safe for human consumption.

Storage

Slide 11

Storage of water in a public water supply serves several purposes, which will be discussed in greater detail in module 7. Different types of storage facilities may be required: ground, elevated, and/or standpipe. The water utility employee is required to inspect and maintain these storage facilities.

Distribution

Slide 12

Distribution involves transporting water from its source through a treatment system, into storage, and finally to the customer. The water utility employee is involved in all stages of this process. Distribution will be discussed in greater detail in module 7.

State Requirements

Slide 13

In Texas the water utility operator is required to notify the TCEQ about changes to a public water system including the following:

- Changes in water source
- Changes in water quality
- Health hazards
- Before starting construction, the water utility must submit engineering plans to the TCEQ for approval.

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Records

Slide 14

Recordkeeping should be a high priority for the water utility operator. Records can aid the operator in many ways. For example, they can assist in:

- planning future construction,
- keeping material and equipment on hand,
- determining work hours for each job, and
- budgeting.

Slide 15

The operator must keep records of water usage, system pressure, sample results, chlorine use, repairs, and maintenance.

Reports

Slides 16-17

Texas public water systems (PWS) are required (30 TAC Chapter 290) to compile a monthly report indicating the amount of chemicals used, daily pumpage, dates of dead-end flushing, cleaning of storage tanks, and results of microbiological and chemical tests. Surface water systems also report raw and treated water analyses and daily turbidity analyses.

Slide 18

Water systems shall submit routine reports and any additional documentation that the executive director may require to determine compliance with the requirements of the rules. The reports must be submitted to the Texas Commission on Environmental Quality, Water Supply Division, by the tenth day of the month following the end of the reporting period. The reports must contain all the information required by the drinking water standards and the results of any special monitoring tests that have been required. The reports must be completed in ink, typed, or computer-printed, and must be signed by the licensed operator having the responsibility for the day-to-day operation of the system (generally/usually the chief operator) (Figure 3.2, Figure 3.3, and Figure 3.4).

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MONTHLY OPERATING REPORT

FOR PUBLIC WATER SYSTEMS THAT ARE USING GROUNDWATER SOURCES
OR ARE PURCHASING TREATED WATER FROM ANOTHER PUBLIC WATER SYSTEM

PUBLIC WATER SYSTEM NAME: _____ **PWS ID No.:** _____

Report for the Month of: _____ **Number of Active Service Connections this Month:** _____

	WATER PRODUCTION					
	Pumpage to storage and distribution X 1000 Gals					
Date	From Wells Directly to Distr.	From Wells to Storage Tanks	Purchased Water Directly to Distr.	Purchased Water into Storage	From SWTP or GWUDI Plant	Total Daily Production
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
Total						
Avg						
Max						
Min						

Any additional information you wish to provide: _____

I certify that I am familiar with the information contained in this report and that, to the best of my knowledge, the information is true, complete, and accurate.

Operator's Signature: _____ **Date:** _____

Certificate No. and Class: _____

TCEQ - 0811 (DRAFT 7-4-06) GW-PWMOR

Figure 3.2: Monthly Operating Report (TCEQ-0811). *Source: TCEQ.*

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SURFACE WATER MONTHLY OPERATING REPORT

FOR PUBLIC WATER SYSTEMS THAT ARE USING SURFACE WATER SOURCES OR GROUND WATER SOURCES UNDER THE INFLUENCE OF SURFACE WATER

Summary Page

PUBLIC WATER SYSTEM NAME: _____ **PLANT NAME OR NUMBER:** _____

PWS ID No.: _____

Plant ID No.: _____ **Operator's Signature:** _____

I certify that I am familiar with the information contained in this report and that, to the best of my knowledge, the information is true, complete, and accurate.

Report for the Month of: _____ **Certificate No. & Grade:** _____ **Date:** _____

TREATMENT PLANT PERFORMANCE

Total number of turbidity readings:		Number of 4-hour periods when plant was off-line:	
Number of readings above 0.10 NTU:		Number of 4-hour periods when plant was on-line but turbidity data was not collected:	
Number of readings above 0.3 NTU:			
Number of readings above 0.5 NTU:		Number of days when plant was on-line but individual filter turbidity data was not collected:	
Number of readings above 1.0 NTU:			
Maximum allowable turbidity level:	0.3	Number of days with readings above 1.0 NTU:	(2)
Percentage of readings above this limit:	% (1)	Number of days with readings above 5.0 NTU:	(3)

Statistical Summary

Maximum turbidity reading:	NTU	Average turbidity value:	NTU
Minimum turbidity reading:	NTU	Standard deviation:	NTU
CFE 95th percentile value:	NTU	IFE 95th percentile:	NTU

Number of days with a low CT for no more than 4.0 consecutive hours:		Average log inactivation for Giardia:	
		Average log inactivation for viruses:	
Number of days with a low CT for more than 4.0 consecutive hours:	(4)	Number of days when profiling data was not collected:	
		Number of days when CT data was not collected:	

Minimum disinfectant residual required leaving the plant: 0.5 mg/L, measured as Total Chlorine

Number of days with a low residual for no more than 4.0 consecutive hours:			
Number of days with a low residual for more than 4.0 consecutive hours:	(5)	Number of days when disinfectant residual leaving the plant was not properly monitored:	

DISTRIBUTION SYSTEM

Minimum disinfectant residual required in distribution system: 0.5 mg/L, measured as Total Chlorine

Total number of readings this month:			
Average disinfectant residual value:		Percentage of readings with a low residual this month:	% (6A)
Number of readings with a low residual:			
Number of readings with no detectable residual:		Percentage of readings with a low residual last month:	% (6B)

ADDITIONAL REPORTS & WORKSHEETS

Additional report(s) for individual filter monitoring required:	◉ NONE	○ Filter Profile		○ Filter Assessment		○ CPE	
Additional report(s) for individual filter monitoring submitted:	◉ NONE	○ Filter Profile (9)		○ Filter Assessment (10)		○ CPE (11)	

No additional IFE Reports are required this month.

SURFACE WATER MONTHLY OPERATING REPORT
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
WATER SUPPLY DIVISION/PUBLIC DRINKING WATER SECTION (MC-155)
P.O. BOX 13087, AUSTIN, TEXAS 78711-3087

TCEQ - 0102C-MGD (Rev. 02-15-16) **PAGE 1** **SWMOR**

Figure 3.3: Surface Water Monthly Operating Report—Page 1. *Source: TCEQ.*

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SURFACE WATER MONTHLY OPERATING REPORT

FOR PUBLIC WATER SYSTEMS THAT ARE USING SURFACE WATER SOURCES OR GROUND WATER SOURCES UNDER THE INFLUENCE OF SURFACE WATER (cont.)

Summary Page Addendum (Violations and Public Notices)

PUBLIC WATER SYSTEM NAME: _____ **PLANT NAME OR NUMBER:** _____

PWS ID No.: _____ **Month:** _____ **Year:** _____

PUBLIC NOTICES

VIOLATION TYPE	DESCRIPTION OF VIOLATION	VIOLATION OCCURRED?	NOTICE TO TCEQ DATE OF NOTICE	NOTICE TO CUSTOMER * DATE OF NOTICE	NOTICE TO CUSTOMER * PENDING	VIOLATION DATES
TREATMENT TECHNIQUE	Were more than 5.0% of the turbidity readings above the acceptable level? - see (1) on the *Summary Page*					
	Were there any days with turbidity readings above 1.0 NTU? - see (2) on the *Summary Page*					
	Were there any days with turbidity readings above 5.0 NTU? - see (3) on the *Summary Page*					
	Were there any periods when the plant failed to meet the CT requirements for more than 4.0 consecutive hours? - see (4) on the *Summary Page*					
	Were there any periods when the residuals leaving the plant fell below the acceptable level for more than 4.0 consecutive hours? - see (5) on the *Summary Page*					
	Were more than 5.0% of the residuals in the distribution system below the acceptable level for two months in a row? - see (6A) and (6B) on the *Summary Page*					
MONITORING & REPORTING	Were there any days when the plant failed to report all of the required Combined Filter Effluent (CFE) turbidity readings? - see the *Turbidity Data Page*					
	Were there any days when the plant failed to report all the CT data needed to evaluate the level of microbial inactivation achieved? - see the *Disinfection Data Page*					
	Were there any days when the plant failed to report the minimum disinfectant residual entering the distribution system? - see the *Turbidity Data Page*					
	Did the system fail to collect enough samples in the distribution system to meet the minimum disinfectant monitoring requirements? - see (8) on the *Summary Page*					
	Were there any days when the plant failed to report the maximum individual filter effluent (IFE) turbidity level produced by each filter? - see the *Filter Data Page*					
	Were there any days when the plant failed to report the IFE turbidity level 4-hours after beginning a filter run? - see the *Filter Data Page*					
	Did the plant fail to submit a Filter Profile Report if one was required? - see (9) on the *Summary page*					
	Did the plant fail to submit a Filter Assessment Report if one was required? - see (10) on the *Summary Page*					
	Did the plant fail to submit a Comprehensive Performance Evaluation Request if one was required? - see (11) on the *Summary Page*					
	Did the plant fail to collect at least one Total Organic Carbon sample set? - *see TOCMOR Page*					

= Treatment technique violation notices are due no later than the end of the next business day. Please include a copy if possible.

* Copies of each Public Notice must accompany this report if they have already been issued.

SUMITTED BY: _____ **Certificate No. and Grade:** _____ **Date:** _____

TCEQ - 0102C-MGD (Rev. 02-15-16) PAGE 1 - Addendum SWMOR

Figure 3.3: Surface Water Monthly Operating Report *(continued)*

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DISINFECTANT LEVEL QUARTERLY OPERATING REPORT (DLQOR)

FOR GROUNDWATER OR PURCHASED-WATER PUBLIC WATER SYSTEMS-ANY SIZE

Select Quarter: _____ Select Year: _____

PWS Name:	PWS ID:

Type of Disinfectant Used in Distribution System*: _____

* If you used chloramines and free chlorine at any time during this quarter, select both.

First Month of Quarter: Monthly Summary

Month: Was the PWS active this month? (•) YES ( ) NO

Average of all disinfectant residuals for this month	Number of residuals collected this month	Number below MIN for this month	Number with NO residual for this month
mg/L	readings	readings %	readings %

Second Month of Quarter: Monthly Summary

Month: Was the PWS active this month? (•) YES ( ) NO

Average of all disinfectant residuals for this month	Number of residuals collected this month	Number below MIN for this month	Number with NO residual for this month
mg/L	readings	readings %	readings %

Third Month of Quarter: Monthly Summary

Month: Was the PWS active this month? (•) YES ( ) NO

Average of all disinfectant residuals for this month	Number of residuals collected this month	Number below MIN for this month	Number with NO residual for this month
mg/L	readings	readings %	readings %

Quarterly Summary and Certification

Average of all disinfectant residuals for this quarter	Lowest residual for this quarter	Highest residual for this quarter
mg/L	mg/L	mg/L

☐ I certify that I am familiar with the information contained in this report and that, to the best of my knowledge, the information is true, complete, and accurate.

Name: _____ Today's Date: 4/1/11
Enter Name Signature

Title: _____ Phone Number: _____

License #: _____ Email address: _____

Complete this form for the previous quarter at the beginning of April, July, October, and January; and submit in time for it to be **received** by the TCEQ by the 10th of the month. Always print and sign form, and keep a copy with your records for TCEQ review.

Step 1: Print Copy (For your own records)

Step 2: Print to Mail

Sign and Mail to:
TCEQ / PDW MC-155
Attn: DLQOR
PO Box 13087
Austin, TX 78711-3087

Click the button below to start over or to reset to enter data for a different system.

Clear Form

TCEQ-20067 (Revised 03/29/2011) **DLQOR**

Figure 3.4: Disinfectant Level Quarterly Operating Report. *Source: TCEQ.*

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Water Characteristics

Water is never found pure in nature. When water falls as rain, impurities are picked up from the air. As the water passes over or through the earth's surface, other impurities are dissolved or suspended. Impurities give water characteristics that concern operators.

Physical Characteristics

Learning Check

1. What is a physical characteristic?

   a. Things you can see, touch, taste, smell and hear

Slide 19

The physical characteristics of water include temperature, turbidity, color, taste, and odor.

Temperature

Compared to the seasonal and day-to-night temperature changes of surface water, the temperature of groundwater is constant. Shallow groundwater, approximately 60 feet or less, may change several degrees with the seasons. It averages 2°F–3°F warmer than the average annual air temperature. Below 60 feet, groundwater temperature increases about 8°F for every 500 feet of depth. However, there are exceptions. Dialville in central east Texas has well water of 120°F from 3,000 feet. Falls City, approximately 30 miles southeast of San Antonio, has well water of 130°F–150°F from 3,800 feet. Water in lakes and reservoirs tends to stratify in layers of different temperature. Temperature affects water quality, thus it is important to draw water from temperature levels with the best quality.

Turbidity

Turbidity is the amount of suspended matter, such as clay, silt, organic matter, and microorganisms, in water. Turbidity gives water a murky or turbid look. While most groundwater is relatively free of suspended matter, turbidity can be a major problem in surface water. A system's filtered water must be 0.3 Nephelometric Turbidity Units (NTU) or less in at least 95% of the measurements taken each month, and no sample can exceed one NTU.

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Color

Color in water can result from mineral or organic matter. True color is dissolved in water (in solution) and cannot be removed by filtering. Tea in water is an example of true color. Other color, such as the red water caused by oxidized iron, is in suspension and can be filtered out. Suspended color is called apparent color. Color above 15 units is objectionable in a public water supply.

Color is measured by comparison of the sample to known concentrations of colored solutions or against colored glass disks. A color unit is produced by 1 mg/L platinum. Twenty units is almost undetectable and 300 units is the color of weak tea.

Iron and manganese exist in both the dissolved and suspended states. As long as they are dissolved, no staining or color problems occur. When the iron or manganese come out of solution into the suspended state, color and staining occur. When these constituents are in sufficient concentrations to cause problems, removal may be required. Aeration or chlorination at the proper pH will oxidize the iron or manganese, causing precipitates to form. These precipitates can then be removed by settling or filtration.

Taste and Odor

Taste and odors in water result from algae, bacteria, decaying organic matter, gases, and chemicals such as manganese, zinc, copper, iron, magnesium, sodium, and potassium.

A scale called the Threshold Odor Number (TON) measures odor. The scale relates to the number of dilutions required before the sample is odorless. Odor greater than a scale of three is undesirable.

Taste and odor may be controlled by aeration or by using chlorine, chlorine dioxide, activated carbon, potassium permanganate, or lake destratification. Destratification provides dissolved oxygen content at all reservoir levels, uniform temperatures, and a thorough mixing of the strata involved.

Iron and manganese exist in both the dissolved and suspended states. As long as they are dissolved, no staining or color problems occur. When the iron or manganese come out of solution, into the suspended state, color and staining occur. When these constituents are in sufficient concentrations to cause problems, removal may be required. Aeration or chlorination at the proper pH will oxidize the iron or manganese, causing precipitates to form. These precipitates can then be removed by settling or filtration.

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Chemical Characteristics

Slide 20

Chemical characteristics include hardness, pH, solids, and gases. Sight, smell, or taste generally cannot detect the presence of dissolved chemicals. Chemical impurities are determined by laboratory analysis. Samples must be taken on treated water as furnished to the customer.

For chemical analysis, surface supplies are sampled once a year and groundwater is normally sampled every three years.

Chemicals in water are expressed in milligrams per liter (mg/L). In water, which weighs 8.34 lbs/gal, 1 mg/L is equal to one part per million (ppm) by weight.

Instructor Note

- *Sight, smell, or taste generally cannot detect the presence of dissolved chemicals.*
- *Chemical impurities are determined by laboratory analysis.*
- *Samples must be taken on treated water as furnished to the customer.*
- *For chemical analysis, surface supplies are sampled once a year and groundwater is normally sampled every three years.*
- *Chemicals in water are expressed in milligrams per liter (mg/L). In water, (1mg/L is equal to 1 part per million (ppm) by weight.*

Hardness

Slide 21

Calcium and magnesium and other minerals cause hardness in water. Hard water makes soap difficult to lather and scale forms on plumbing. Hardness is more of a problem in groundwater than surface water. Water is considered hard when it exceeds 100 mg/L of calcium carbonate.

Learning Check

1. What is the level of hardness in your water?

   a. Ours is less than 10.

   b. Ours is 125.

   c. Ours is 70.

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pH

Slide 22

pH is a measure of the hydrogen ion concentration in water, or how acidic or basic a solution is. The pH scale ranges from 0 to 14. From 0 to <7 is acidic and from >7 to 14 is basic or alkaline. A pH of 7 is neutral. If water has a pH of 6.5, it is slightly acidic. If the pH is 7.8, the water is slightly basic. A pH of 8.5 is more basic than a pH of 7.8.

Sulfuric, hydrochloric, and nitric acids will lower the pH below 7. Alkalis such as caustic, lime, or soda ash will raise the pH above 7.

pH is important in coagulation, corrosion control, prevention of scale, and chlorination. Red water caused by oxidized iron is influenced by pH.

Solids

Slide 23

One analysis of chemical water quality is the quantity of solids:

- Suspended solids can be removed by filtration.
- Dissolved solids cannot be removed by filtration. Total dissolved solids should not exceed 1,000 mg/L.
- Total solids are the sum of dissolved and suspended solids. High concentrations of solids cause scale in equipment and taste in drinking water.

Gases

Slide 24

Common gases found in water include hydrogen sulfide (which has a rotten egg odor), carbon dioxide, and methane. Gases come from mineral deposits or are given off by decaying organic matter.

Hydrogen sulfide is heavier than air, colorless, flammable, and toxic. Carbon dioxide is heavier than air, odorless, colorless, does not burn, and is suffocating. Methane is lighter than air, odorless, colorless, and explosive.

Water Quality Standards

Standards

Safe Drinking Water Act—PL-93-523

Maximum Contaminant Levels (MCL)

As prescribed by the United States Environmental Protection Agency

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Maximum Inorganic Chemical Contaminant Levels

Slide 25

Maximum Contaminant Levels (MCL) are outlined in the Safe Drinking Water Act. Table 3.1 provides the maximum contaminant levels for inorganic chemicals as described in the Safe Drinking Water Act PL-93-523.

Table 3.1: Inorganic Chemicals—Maximum Contamination Levels

Contaminant	mg/L	Applicable System
Antimony	0.006	CN
Arsenic	0.010	CN
Asbestos	7 million fibers/liter (longer than 10 μm)	CN
Barium	2	CN
Beryllium	0.004	CN
Cadmium	0.005	CN
Chromium	0.1	CN
Cyanide	0.2 (as free Cyanide)	CN
Fluoride	4	C
Mercury	0.002	CN
Nitrate	10 (as nitrogen)	CNT
Nitrite	1 (as nitrogen)	CNT
Nitrate & Nitrite	10 (as nitrogen)	CNT
Selenium (Total)	0.05	CN
Thallium	0.002	CN

C = Community
N = Non-transient, non-community
T = Transient, non-community

Arsenic, mercury, and thallium are highly toxic metals.

Nitrate. At the discretion of the state, nitrate levels not to exceed 20 mg/L (as nitrogen) may be allowed in a non-community system if the supplier of water demonstrates to the satisfaction of the state that such water will not be available to children under six months of age.

Excess nitrogen causes “blue baby” syndrome (methemoglobinemia), a disease that prevents red blood cells from carrying oxygen, and resulting in suffocation and blue skin color. Baby formula made with water high in nitrogen compounds is the danger. Children older than six months and adults are not at risk.

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The major source of nitrogen is fertilizer and animal waste from dairies, hog farms, and feedlots. Rainwater runoff carries nitrogen compounds into drinking water sources such as lakes and rivers, or the runoff percolates into aquifers.

The standards are expressed as mg/L of nitrate nitrogen content. 10 mg/L of nitrate nitrogen equals 44 mg/L of nitrate compound.

Fluoride. The EPA primary MCL for fluoride is 4.0 mg/L; and at this level, it will causes mottling of teeth, a condition known as fluorosis. The tooth enamel is eaten away by the high fluoride concentrations. The State of Texas secondary standard for fluoride is 2.0 mg/L. Concentrations higher than this may cause staining of the teeth. People routinely drinking water with fluoride levels between 2.0 and 4.0 mg/L will have brown teeth. In low concentrations, fluoride has been shown to reduce dental cavities. Water systems that have chosen to add fluoride maintain a maximum concentration of 0.7 mg/L.

Maximum Organic Chemical Contaminant Levels

Table 3.2 defines the maximum contaminant levels for a partial list of man-made organic chemicals, including pesticides and herbicides, in community water systems.

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Table 3.2: Organic Chemicals—Maximum Contamination Levels

Contaminant	mg/L	Constituent	mg/L
Alachlor	0.002	Ethylbenzene Dibromide (EDB)	0.00005
Atrazine	0.003	Heptachlor	0.0004
Benzene	0.005	Heptachlor or Epoxide	0.0002
Carbofuran	0.04	Lindane	0.0002
Carbon Tetrachloride	0.005	Methoxychlor	0.04
Chlordane	0.002	Pentachlorophenol	0.001
2,4-D	0.07	Polychlorinated Biphenyls (PCB)	0.005
Dibromochloropropane (DBCP)	0.0002	Styrene	0.1
o-Dichlorobenzene	0.6	Tetrachloroethylene	0.005
p-Dichlorobenzene	0.075	Toluene	1
1,2-Dichloroethane	0.005	Toxaphene	0.003
1,1-Dichloroethylene	0.007	2,4,5-TP (Silvex)	0.05
cis-1,2-Dichloroethylene	0.07	1,1,1-Trichloroethane	0.2
trans-1,2-Dichloroethylene	0.1	Trichloroethylene	0.005
1,2-Dichloropropane	0.005	Vinyl Chloride	0.002
Endrin	0.002	Xylenes (total)	10
Ethylbenzene	0.7		

Turbidity

This standard applies to systems that treat surface water and to any groundwater under the influence of surface water (e.g. shallow wells).

A system's combined filter effluent must be less than or equal to 0.3 NTU in at least 95% of the measurements taken each month and no sample can exceed one NTU.

Trihalomethanes (THM) and Haloacetic Acids (HAA)

Preventing THM and HAA Formation

Trihalomethanes (THM) and Haloacetic Acids (HAA) are byproducts of drinking water chlorination. These byproducts form when chlorine reacts with dissolved natural organic matter, mostly plant life. These byproducts may cause problems with the liver, kidneys, or central nervous systems, and may increase cancer risk. Also, THMs have possible reproductive health risks.

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Surface water usually contains natural organics and groundwater usually does not. Therefore, most surface water treatment plants are required to combine chlorine with ammonia (chloramine) before disinfecting the treated water. Combining chlorine with ammonia greatly reduces THM and HAA formation. Systems using groundwater that does not contain natural organics (most do not) are allowed to use uncombined chlorine, called free chlorine.

THMs and HAAs MCLs

The MCL for total trihalomethanes is 0.08 mg/L and the MCL for HAA_5 is 0.06 mg/L. These MCLs apply to all community and non-transient, non-community water systems using surface water or groundwater under the direct influence of surface water, and groundwater systems serving at least 10,000 persons.

Public Notification Requirements

A public water system failing to comply with an MCL or treatment technique that poses an acute risk to public health shall notify persons served by the system within 45 days after the violation as follows:

1. Publication in a daily newspaper serving the system. If none exists, the notice shall be issued by hand delivery or by posting in conspicuous places within the area served.
2. Furnish a copy of the notice to radio and television stations serving the area.

The system telephone number must be included and be multilingual, if necessary. Other rules may apply.

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Secondary Contaminant Levels

Table 3.3 shows the levels of secondary contamination as adopted by the State of Texas.

Table 3.3: Secondary Contaminant Levels as Adopted by the State

Contaminant	Level
Aluminum	0.05 to 0.2 mg/L[2]
Chloride	300 mg/L
Color	15 color units
Copper	1.0 mg/L
Corrosivity	non-corrosive
Foaming Agents	0.5 mg/L
Fluoride	2.0 mg/L
Hydrogen Sulfide	0.05 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg.L
Odor	3 threshold odor number
pH	>7.0
Silver	0.10 mg/L[3]
Sulfate	300 mg/L
Total Dissolved Solids (TDS)	1000 mg/L
Zinc	5 mg/L
These limits cannot be exceeded without written permission from the TCEQ.	

The Lead and Copper Rule

Slide 26

To reduce lead and copper in public drinking water, EPA adopted the Lead and Copper Rule in 1991. The rule applies to community and non-transient, non-community water systems.

Corrosive water leaches lead and copper from plumbing fixtures and service lines. Copper is an essential nutrient, but in excess amounts can cause gastrointestinal distress or liver or kidney damage. Lead can impair physical or mental development in children and cause kidney problems or high blood pressure in adults.

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Instead of setting MCLs, EPA set Maximum Contaminant Level Goals (MCLG) at zero for lead and 1.3 mg/L for copper. MCLGs are non-enforceable, optimal health-based targets. However, the Lead and Copper Rule requires Action Steps.

If sampling indicates lead exceeds 0.015 mg/L or copper exceeds 1.3 mg/L (action levels) in 10% or more samples, the water system must take prescribed action. Prescribed actions include source water treatment, corrosion control, public education, and possible replacement of lead service lines.

Sampling Requirements

Samples for lead and copper are to be taken at high-risk locations such as homes with lead solder installed after 1982, homes with lead pipes, and homes with lead service lines.

Water in the pipe must not flow for six hours (but no longer than 18 hours) before sample collection. Then a one-liter, first-draw sample is taken from the cold water kitchen or bathroom tap. The samples must not be drawn from the hot water tap because lead dissolves more easily into hot water. Utility personnel or trained residents may take samples, and utility personnel will take the samples to an approved lab.

Water systems that meet the action levels or maintain corrosion control for two consecutive six-month periods may reduce sampling to once per year. Water systems meeting requirements for three consecutive years may reduce sampling to once every three years (Table 3.4).

Table 3.4: Sampling Requirements for Lead and Copper

System Population Size	No. of Sampling Sites (Initial Sampling)	No. of Sampling Sites (Reduced Monitoring)
10,000 to 100,000*	60	30
3,301 to 10,000	40	20
501 to 3,300	20	10
101 to 500	10	5
> 101	5	5

*** Systems greater than 100,000 population are required 100 initial sites and 50 reduced sites.**

Prescribed Action

If 10% or more samples exceed the action levels of 0.015 mg/L for lead or 1.3 mg/L for copper, the water systems must take prescribed actions, such as sampling the water source for lead or copper.

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If treatment is required, the state may specify a treatment such as the following:

- Ion Exchange: This is accomplished by exchanging calcium Ca2+ and magnesium Mg2+ cations against sodium Na+ or hydrogen H+ cations.
- Reverse Osmosis: In simple terms, reverse osmosis is the process of pushing a solution through a filter that traps the solute on one side and allows the pure solvent to be obtained from the other side.
- Lime Softening: In lime softening, hydrated lime (calcium hydroxide, Ca(OH)2) is added to water to precipitate calcium carbonate before the water is used. The amount of lime required will depend on hardness levels. The process requires a settlement period and its effectiveness is governed by the pH of the water.
- Coagulation and Filtration: This process is surface water treatment, which is detailed in module 5.

If the water source does not contain lead or copper, the system must submit to the state a plan for corrosion control such as pH and alkalinity adjustment, or addition of phosphate or silica corrosion inhibitors.

Water systems that maintain parameters with corrosion control over two consecutive six-month periods may reduce sampling during each six-month period. If parameters are maintained for three consecutive years, sampling may be reduced to once per year.

Public Notification

All public water systems exceeding the lead action level must deliver an EPA public education program to their customers within 60 days. This program informs the public of lead and copper health hazards and ways to minimize exposure in drinking water. Additionally, the system must deliver:

- bill stuffers to consumers and brochures to community institutions frequented by women and children;
- public education material to daily newspapers serving the community (every 12 months); and
- public service announcements to community television and radio stations (every six months).

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After treatment, water systems that exceed action levels must replace lead or copper service lines under utility ownership. The utility must offer to replace customer portions of the service line at owner's expense. The utility is not responsible for private plumbing inside homes.

A system must replace 7% of the service lines each year or demonstrate that the lines not replaced contribute less than the action levels. The system has 15 years to replace the dangerous service lines.

Reducing Lead Exposure

Early in 2011, President Obama signed into law the *Reduction of Lead in Drinking Water Act*, a measure that defines "lead-free" as not containing more than 0.2% lead when used with respect to solder and flux and not more than a weighted average of 0.25% lead when used with wet surfaces of pipes and pipe and plumbing fittings and fixtures. It also establishes a formula to calculate the weighted average of lead content in a pipe or plumbing fitting or fixture. These new limits went into effect January 4, 2014.

Summary

Slide 27

The diversity and dissection of water and its sources is complex. Regulatory agencies and their requirements are vital to our industry in the protection of general public water supplies. In the next module we will investigate groundwater.

In this module, you have learned about the hydrologic cycle and the physical and chemical characteristics of water. In addition, you should be able to describe the various uses of water, including domestic, public, and business. After reading this module, you should also be able to describe water quality standards and the various processes for preparing water for public use. Now that you have been given an overview of the water supply process from the hydrologic cycle to production, we will narrow our focus to the extraction, treatment, and distribution of groundwater.

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Module 3 Review Questions

1. The molecular formula for water is $\mathbf{HO_2}$.
   a. true
   b. **false**

2. Water occurs in three forms: solid ice, liquid water, and water vapor.
   a. **true**
   b. false

3. The hydrologic cycle is the natural exchange of water between the earth and the atmosphere.
   a. **true**
   b. false

4. Average water use depends on temperature, rainfall, cost, supply, and economic level.
   a. **true**
   b. false

5. Groundwater is located **above** the earth's surface and tapped by wells.
   a. true
   b. **false**

6. Surface water comes from rivers, lakes, and reservoirs.
   a. **true**
   b. false

7. Future water supplies will become **more** plentiful according to the TCEQ.
   a. true
   b. **false**

8. Surface water or groundwater prior to treatment is called **fresh** water.
   a. true
   b. **false**

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9. Potable water means the water is free of disease-causing organisms, has a chlorine residual, and is safe for human consumption.

   a. **true**

   b. false

10. The state must be notified about changes to public water systems involving water source, water quality, and health hazards.

    a. **true**

    b. false

11. Before starting construction, the utility must submit engineering plans to the **AWWA**.

    a. true

    b. **false**

12. Operators must keep records of water usage, system pressure, sample results, chlorine use, repairs, and maintenance.

    a. **true**

    b. false

13. Surface water systems must mail reports to the TCEQ in Austin by the **5th** of the following month.

    a. true

    b. **false**

14. Water is **always** found pure in nature.

    a. true

    b. **false**

15. Physical characteristics of water are temperature, turbidity, color, taste, odor, and **pH**.

    a. true

    b. **false**

16. Turbidity is the amount of suspended matter such as clay, silt, organic matter, and microorganisms in the water.

    a. **true**

    b. false

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17. Color in water can result from mineral or organic matter.

    a. **true**

    b. false

18. True color is dissolved in water (in solution) and **can** be removed by filtration.

    a. true

    b. **false**

19. Red water caused by oxidized iron is in suspension (apparent color) and **cannot** be removed by filtering.

    a. true

    b. **false**

20. Taste and odor comes from algae, bacteria, organic matter, gases, and chemicals.

    a. **true**

    b. false

21. Surface water supplies should be sampled for chemical analysis every year and groundwater supplies should be sampled **three times a year**.

    a. true

    b. **false**

22. Calcium and magnesium and other minerals cause hardness in water.

    a. **true**

    b. false

23. The pH scale ranges from **1** to 14.

    a. true

    b. **false**

24. A pH of 7 is neutral.

    a. **true**

    b. false

25. Suspended solids can be removed by filtering and dissolved solids cannot.

    a. **true**

    b. false

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26. Common gases found in water include hydrogen sulfide, carbon dioxide, methane, and **sodium chloride**.

    a. true

    b. **false**

27. Chemically, water is made of _____.

    a. one atom of water

    b. one atom of hydrogen and one atom of oxygen

    c. **two atoms of hydrogen and one atom of oxygen**

    d. one atom of hydrogen and two atoms of oxygen

28. The hydrologic cycle is _____.

    a. **nature's way of recycling water**

    b. equipment used to measure distances

    c. the way water filters through the earth

    d. the process by which water runs into rivers and lakes

29. The quality standard for public water supplies is based on the use of water for _____.

    a. firefighting

    b. **drinking**

    c. bathing

    d. swimming

30. One of the most important purposes of a public water supply is _____.

    a. swimming

    b. landscape watering

    c. car washing

    d. **firefighting**

31. Organic matter includes _____.

    a. sand

    b. **plants, animals, and humans**

    c. minerals

    d. all listed

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32. The most important treatment process is _____, which destroys disease-causing organisms.

    a. filtration

    b. **disinfection**

    c. softening

    d. fluoridation

33. Public water systems are required to compile a monthly report showing _____.

    a. rate increases

    b. accidents

    c. **dates of dead-end flushing**

    d. disciplinary action

34. Most groundwater is relatively free of suspended matter, but _____ can be a major problem in surface water.

    a. **turbidity**

    b. gases

    c. sand

    d. hot water

35. Color in a public water supply should be _____.

    a. at least 15 units

    b. less than three units

    c. **less than 15 units**

    d. red

36. Chemical characteristics include hardness, pH, solids, and _____.

    a. **gases**

    b. taste

    c. temperature

    d. color

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37. Water is considered hard when it exceeds _____ mg/L of calcium carbonate.
    a. 0.1
    b. 10
    c. **100**
    d. 1,000

38. A gallon of water weighs 8.34 pounds and 1 mg/L equals one _____.
    a. million grams
    b. thousand grams
    c. part per thousand
    d. **part per million**

39. Hydrogen sulfide is heavier than air, colorless, flammable, toxic, and has a _____ odor.
    a. sweet
    b. **rotten egg**
    c. rotten fish
    d. fragrant

40. Excessive nitrates in drinking water can cause _____ syndrome in infants.
    a. bad baby
    b. blue body
    c. bloody baby
    d. **blue baby**

41. Excessive amounts of fluoride may cause _____ or staining of teeth.
    a. **mottling**
    b. molding
    c. cracking
    d. yellowing

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42. Trihalomethanes and haloacetic acids are byproducts of chlorination and may increase _____ risk.

    a. mottled teeth

    b. red water

    c. typhoid

    d. **cancer**

43. The action level for copper is 1.3 mg/L and for lead it is _____ mg/L.

    a. 15

    b. 1.5

    c. **0.015**

    d. 0.15

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Module 3 Presentation Slides

Basic Water Operations

Module 3
Water Characteristics

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Terminal Objective

Upon successful completion of this module, the participant will be able to describe the attributes of water from various sources.

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Enabling Objectives

- Explain the hydrologic cycle.
- List the various uses of water.
- Describe the preparation of water for public use.
- Describe the physical characteristics, including the sources, of water.
- Discuss water quality standards.

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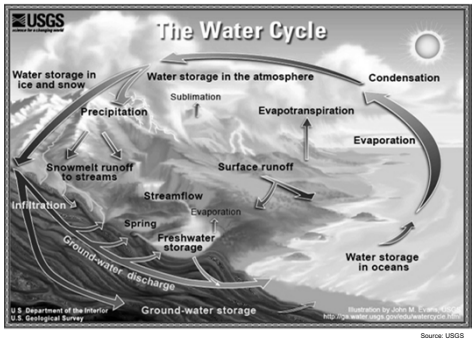
Water Facts

- 75% of the Earth's surface is water
- Fresh water breakdown
  - 75% polar ice caps
  - 25% groundwater
  - ⅓ of 1%, fresh water in lakes
  - 20% in Great Lakes

Water Facts

- Chemical composition (H_2O)
- Three forms
  - Solid – ice at 32°F (0°C)
  - Liquid – 8.34 lbs/Gal, Specific Gravity of 1
  - Vapor – at 212°F (100°C)



Source: USGS

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Uses of Water

- Domestic
  - Drinking, sanitation, and lawn watering
- Public
  - Recreation, fire protection (most important)
- Business
  - Industrial, commercial, agricultural

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Definitions

- Average use
  - Dependent upon temperature, cost, rainfall
  - Amount of supply
  - Economic level
- Maximum use - (peak demand) during drought
- Minimum use occurs in winter months

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Water Production

To produce this much useable water:	You need this much raw water:
Sunday paper	280 gal.
Loaf of bread	300 gal.
McAttack	1,500 gal.
1 pound of beef	4,000 gal.
20 pound turkey	16,800 gal.
4 tires	25,000 gal.
Automobile	100,000 gal.

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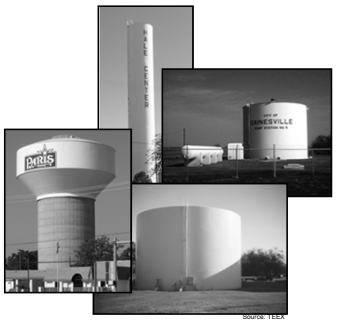
Water Treatment

- Raw water exists prior to treatment
- Organic matter contains carbon
  - Organic chemistry
  - Biochemistry
  - Examples of organic matter
  - Examples of inorganic matter

Storage Facilities



Source: TEEX

- **Ground**
- **Clear well**
- **Elevated**
- **Pressure**
- **Standpipe**

Transportation Distribution

- Movement of water
  - From source to treatment system
  - From treatment system to storage
  - From storage to customer
- Utility employees are involved in all

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State Requirements

- Notify TCEQ about changes to public water system
  - Change in water source
  - Change in water quality
  - Health hazards
- Construction requires prior TCEQ approval

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Need for Records

- Plan for future construction
- Keep material/equipment on hand
- Determine work hours per job
- Budgeting

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Records To Keep

- Water usage
- System pressure
- Sample results
- Chlorine Use
- Repairs
- Maintenance

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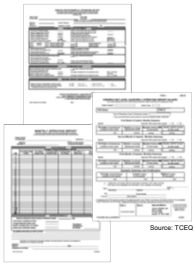
TCEQ Required Reports

- Amount of chemicals used
- Daily pumpage
- Dead end flushing dates
- Storage tank cleaning
- Microbiological, chemical test results



Source: TCEQ

Surface Water Systems

- Raw and treated water analyses
- Daily turbidity analyses
- Disinfectant level for groundwater or other

Report Submission

- Surface water reports by 10th of month
- Contain info for drinking water standards
- Contain special test results
- Completed in ink, typed, printed
- Signed by licensed water operator

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Physical Characteristics of Water

- Temperature – ground, surface vary
- Turbidity – amount of suspended matter
- Color – from minerals, organic matter
- Taste – from algae, bacteria, decay
- Odor – same as taste, chemicals

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Chemical Characteristics of Water

- Hardness – caused by minerals
- pH – measure of hydrogen ion concentration
- Solids – suspended or dissolved
- Gas – mineral deposits, decaying organic matter

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Hardness Scale

0—60	mg/L	Soft Water
61—120	mg/L	Moderate Water
121—180	mg/L	Hard Water
>181	mg/L	Very Hard Water

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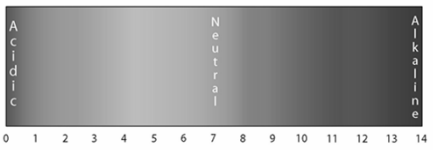
pH Scale

- Hydrogen ion concentration in water
- Ranges from 0 to 14
- Determines treatment required



Solids

- Suspended solids removed by filtration
- Dissolved solids not removed by filtration
- Total = Dissolved + Suspended

Gases in Water

- Hydrogen Sulfide (H_2S)
- Carbon Dioxide (CO_2)
- Methane (CH_4)

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Water Quality Standards

- Nitrogen levels – <20 mg/L
- Fluoride levels - <4 mg/L
- Trihalomethanes- <0.08 mg/L
- Secondary standards
- Lead – 0 mg/L MCLG, 0.015 mg/L Action Level
- Copper - 1.3 mg/L MCLG and Action Level

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Lead/Copper Sampling Requirements

System Population Size	No. Of Sampling Sites (initial sampling)	No. Of Sampling Sites (reduced monitoring)
10,000—100,000*	60	30
3,301—10,000	40	20
50—3,300	20	10
101—500	10	5
less than 101	5	5

** Systems greater than 100,000 population are required 100 initial sites and 50 reduced sites.*

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Module 3

Review Questions

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End of Module 3

Next Module:
Groundwater Production

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28

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Module 4

Groundwater Production

Terminal Objective

Upon the successful completion of this module, the participant will be able to describe how groundwater is made usable.

Enabling Objectives

1. Explain the relationship of aquifers to types of wells.
2. Explain common methods of groundwater treatment.

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Instructional Guidance

Time

2 hours, 50 minutes

Materials/Equipment

1. Participant manual
2. Laptop with presentation slides for module 4
3. Internet connectivity
4. Video/data projector
5. Screen or monitor

Instructor Preparation

Prepare projector and position first presentation slide.

Application of Participants' Knowledge/Skills

Have participants complete the review questions at the end of the module.

Evaluation of Participants

Go over the review questions at the end of the module, answering any questions the participants may still have.

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Introduction

Slides 1-3

In this module, we will discuss sources of groundwater for our earth, as well as major sources in the state of Texas. The discussion will include groundwater withdrawal, sanitation, and treatment.

Sources of Groundwater

Slide 4

The source of about 60% of the water supply in Texas, according to the Texas Water Development Board (TWDB), is from underground supplies and it serves about 1/4 of the population (Figure 4.1). The protection of the wells against bacterial and chemical contamination is a matter of great concern to operators. While well water is usually clear and sparkling, many conditions may endanger the water.

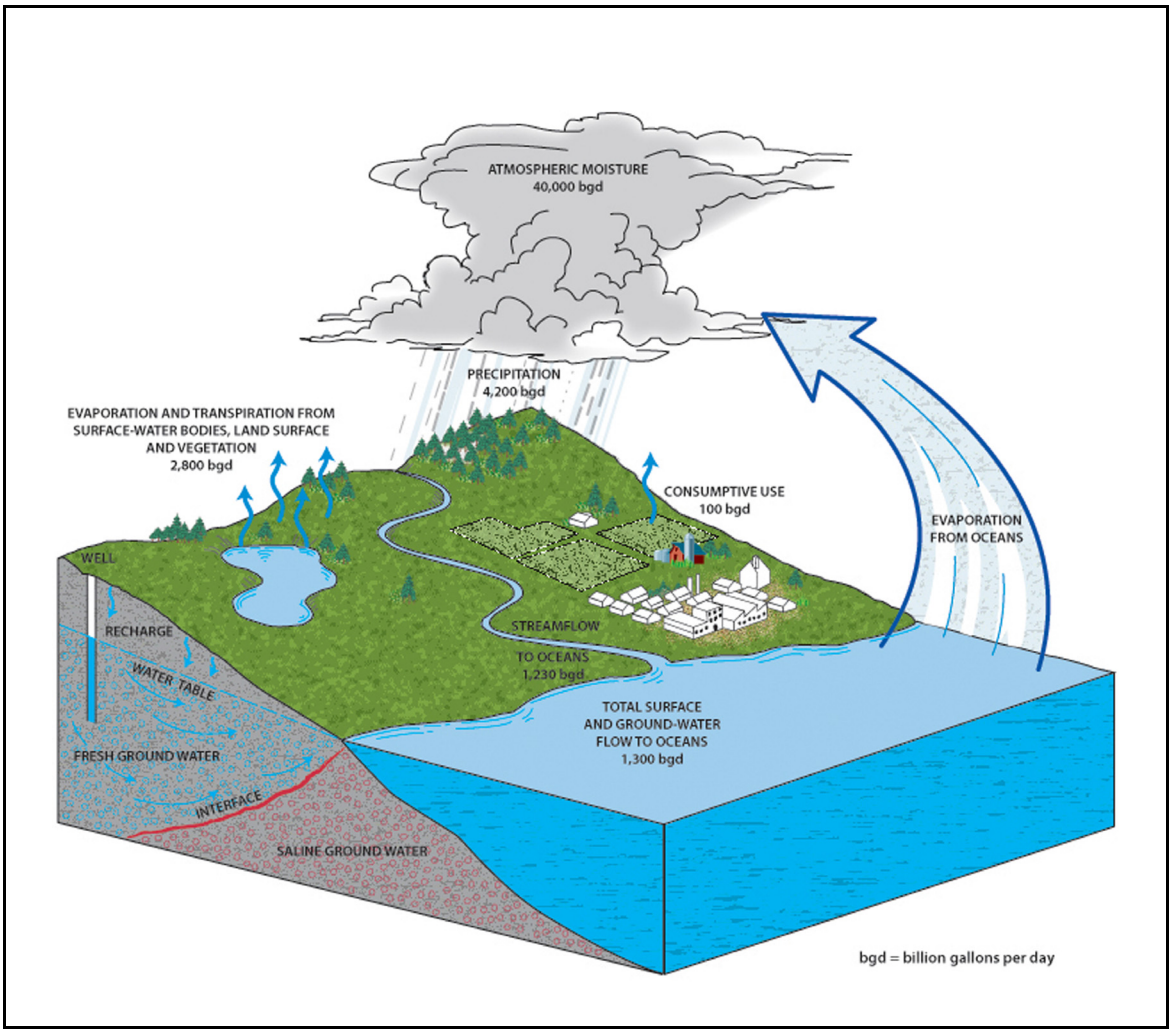

Figure 4.1: Sources of groundwater. *Source: USGS.*

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Aquifers

Slides 5-6

Groundwater occurs below the earth's surface in water-bearing formations called aquifers. An aquifer must yield useful quantities of water to be used as a public water supply. These formations are found at different depths in different parts of the country (Figure 4.2 and Figure 4.3). Thus, it is much easier to locate and harvest groundwater in some areas than in others. Groundwater usually contains more dissolved minerals and gases than surface water, but fewer microorganisms.

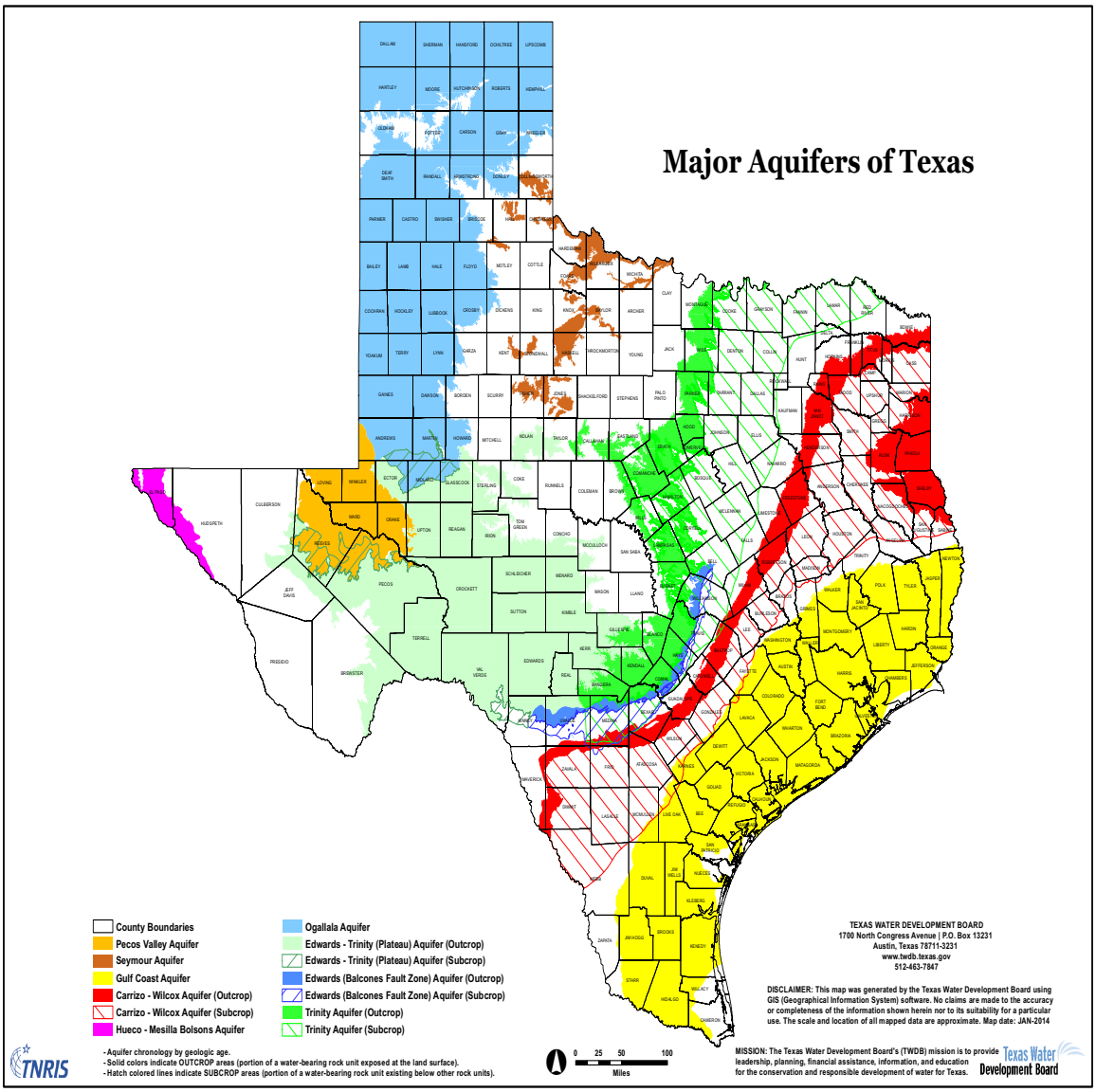
Major Aquifers of Texas
County Boundaries
Pecos Valley Aquifer
Seymour Aquifer
Gulf Coast Aquifer
Carrizo - Wilcox Aquifer (Outcrop)
Carrizo - Wilcox Aquifer (Subcrop)
Hueco - Mesilla Bolsons Aquifer
Ogallala Aquifer
Edwards - Trinity (Plateau) Aquifer (Outcrop)
Edwards - Trinity (Plateau) Aquifer (Subcrop)
Edwards (Balcones Fault Zone) Aquifer (Outcrop)
Edwards (Balcones Fault Zone) Aquifer (Subcrop)
Trinity Aquifer (Outcrop)
Trinity Aquifer (Subcrop)
- Aquifer chronology by geologic age.
- Solid colors indicate OUTCROP areas (portion of a water-bearing rock unit exposed at the land surface).
- Hatch colored lines indicate SUBCROP areas (portion of a water-bearing rock unit existing below other rock units).
0 25 50 100
Miles
TEXAS WATER DEVELOPMENT BOARD
1700 North Congress Avenue | P.O. Box 13231
Austin, Texas 78711-3231
www.twdb.texas.gov
512-463-7847
DISCLAIMER: This map was generated by the Texas Water Development Board using GIS (Geographical Information System) software. No claims are made to the accuracy or completeness of the information shown herein nor to its suitability for a particular use. The scale and location of all mapped data are approximate. Map date: JAN-2014
MISSION: The Texas Water Development Board's (TWDB) mission is to provide leadership, planning, financial assistance, information, and education for the conservation and responsible development of water for Texas.
TNRIS
Texas Water Development Board

Figure 4.2: Major aquifers. *Source: Texas Water Development Board.*

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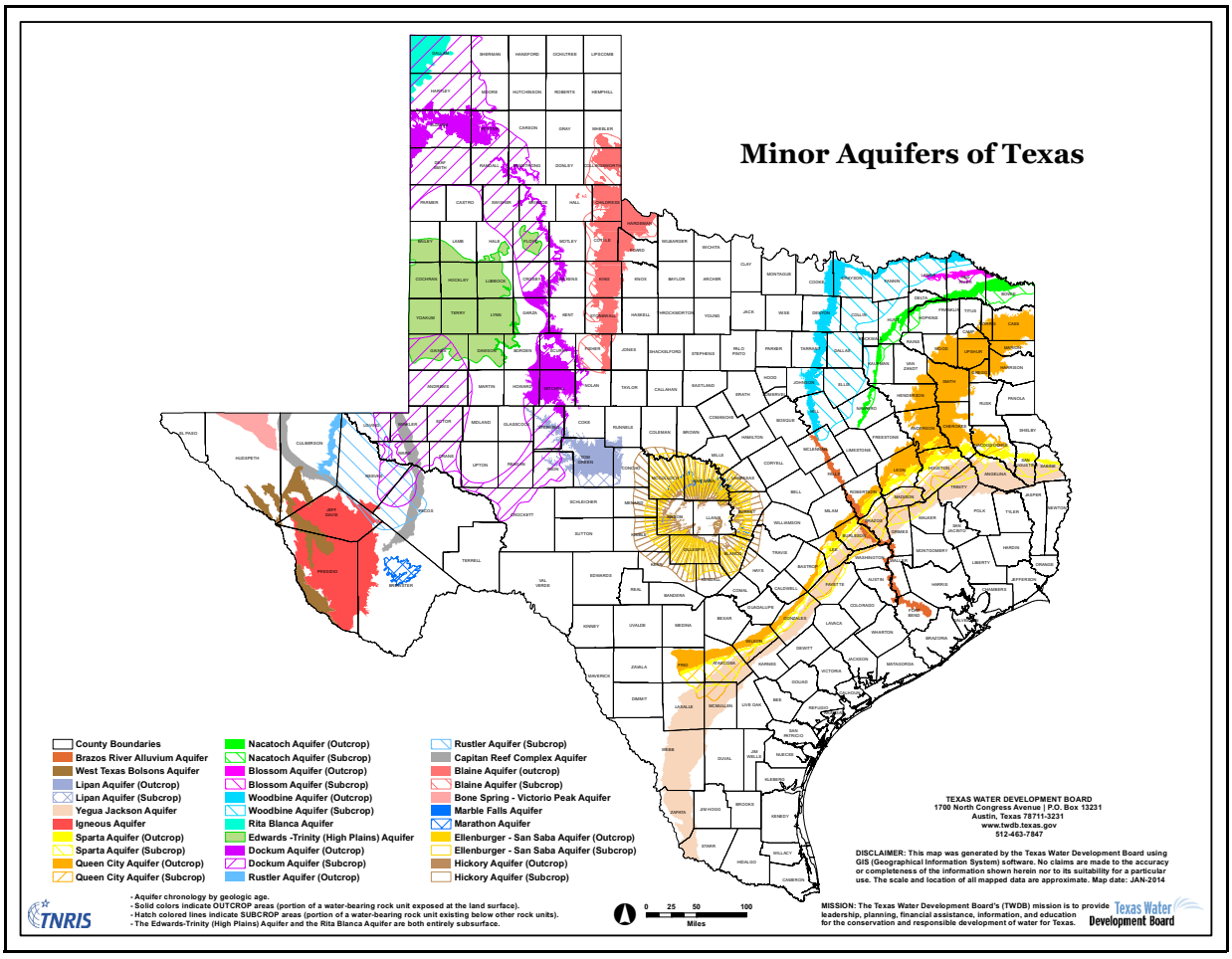
Minor Aquifers of Texas
County Boundaries
Brazos River Alluvium Aquifer
West Texas Bolsons Aquifer
Lipan Aquifer (Outcrop)
Lipan Aquifer (Subcrop)
Yegua Jackson Aquifer
Igneous Aquifer
Sparta Aquifer (Outcrop)
Sparta Aquifer (Subcrop)
Queen City Aquifer (Outcrop)
Queen City Aquifer (Subcrop)
Nacatoch Aquifer (Outcrop)
Nacatoch Aquifer (Subcrop)
Blossom Aquifer (Outcrop)
Blossom Aquifer (Subcrop)
Woodbine Aquifer (Outcrop)
Woodbine Aquifer (Subcrop)
Rita Blanca Aquifer
Edwards -Trinity (High Plains) Aquifer
Dockum Aquifer (Outcrop)
Dockum Aquifer (Subcrop)
Rustler Aquifer (Outcrop)
Rustler Aquifer (Subcrop)
Capitan Reef Complex Aquifer
Blaine Aquifer (outcrop)
Blaine Aquifer (Subcrop)
Bone Spring - Victorio Peak Aquifer
Marble Falls Aquifer
Marathon Aquifer
Ellenburger - San Saba Aquifer (Outcrop)
Ellenburger - San Saba Aquifer (Subcrop)
Hickory Aquifer (Outcrop)
Hickory Aquifer (Subcrop)
- Aquifer chronology by geologic age.
- Solid colors indicate OUTCROP areas (portion of a water-bearing rock unit exposed at the land surface).
- Hatch colored lines indicate SUBCROP areas (portion of a water-bearing rock unit existing below other rock units).
- The Edwards-Trinity (High Plains) Aquifer and the Rita Blanca Aquifer are both entirely subsurface.
TNRIS
0 25 50 100
Miles
TEXAS WATER DEVELOPMENT BOARD
1700 North Congress Avenue | P.O. Box 13231
Austin, Texas 78711-3231
www.twdb.texas.gov
512-463-7847
DISCLAIMER: This map was generated by the Texas Water Development Board using GIS (Geographical Information System) software. No claims are made to the accuracy or completeness of the information shown herein nor to its suitability for a particular use. The scale and location of all mapped data are approximate. Map date: JAN-2014
MISSION: The Texas Water Development Board's (TWDB) mission is to provide leadership, planning, financial assistance, information, and education for the conservation and responsible development of water for Texas.
Texas Water Development Board

Figure 4.3: Minor aquifers. *Source: Texas Water Development Board.*

Groundwater Withdrawal

Slide 7

Groundwater is tapped by means of wells and springs. Shallow wells are usually water table wells. Water table aquifers are not confined from above by a layer of clay or rock.

Deep wells are usually artesian wells. Artesian aquifers are overlaid by an impervious layer of rock. Contrary to popular belief, not all artesian wells are flowing wells. Springs are natural outcrops where an aquifer reaches the surface.

The yield of an aquifer depends on the thickness of the formation and its permeability (how readily it gives up the water).

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Figure 4.4 illustrates water withdrawal from water table wells and artesian wells.

> ***Instructor Note***
>
> *Discuss the differences in the formations between water table wells and artesian wells as shown in Figure 4.4.*

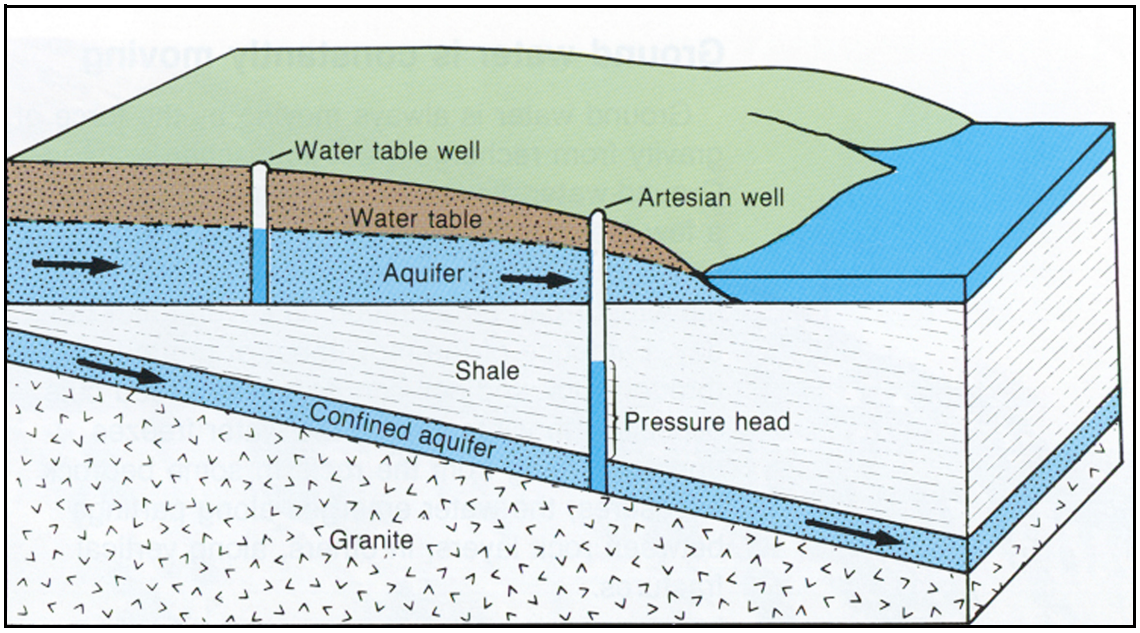

Figure 4.4: Groundwater withdrawal. *Source: USGS.*

Well Location

In a water table well, the cone of depression is an area dewatered by pumping. In an artesian well, a similar area exists where water pressure is reduced. This area is called the zone of pressure reduction. In either well, the top of this area is called the radius, or circle of influence (Figure 4.5).

The radius, or circle of influence, of a well is an important factor in deciding the location of a new well. Wells should be located far enough apart that their circles of influence do not overlap. If they do overlap, pumping levels may be reduced in both wells.

Drawdown Profiles

Refer to Figure 4.5 below.

1. Drawdown profile when well Number 1 is pumped alone.
2. Drawdown profile when well Number 2 is pumped alone.

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3. Drawdown profile resulting from interference when both wells are pumped at the same time.

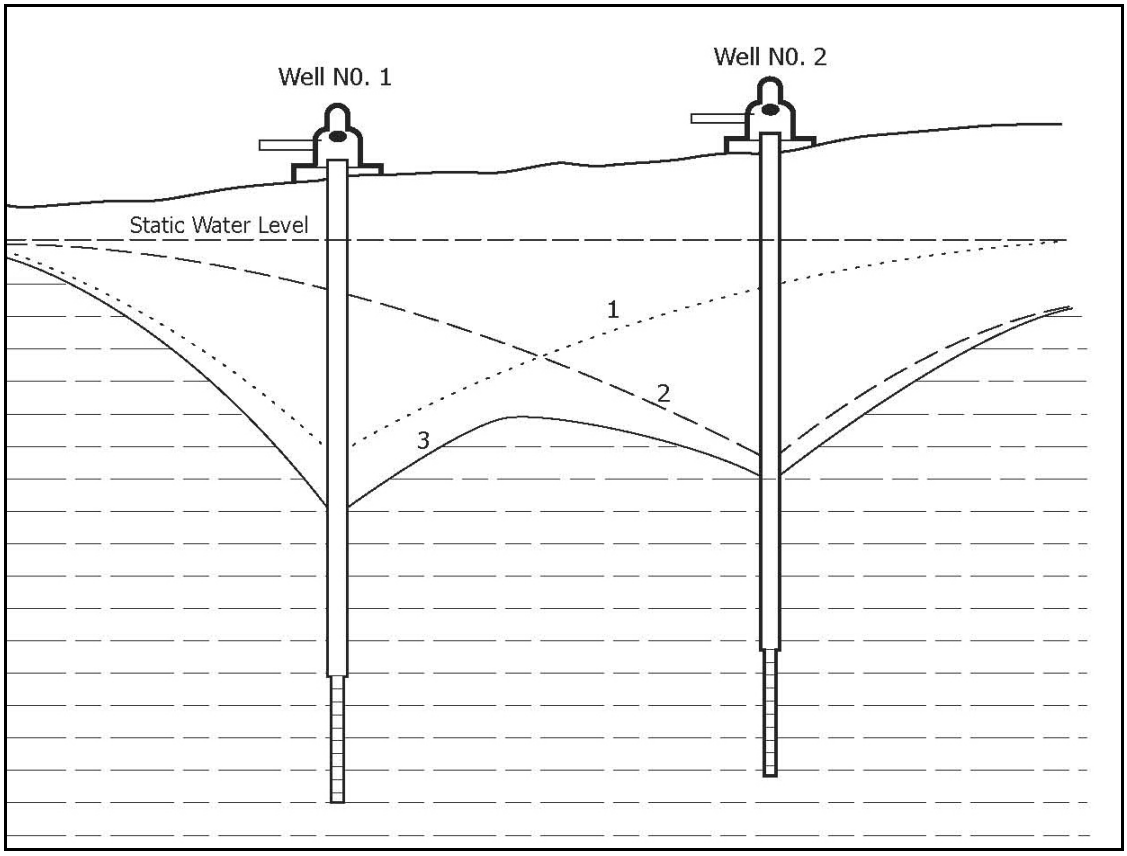

Figure 4.5: Overlapping drawdown profiles. *Source: TEEX*

Groundwater Recharge

Slide 8

Aquifers are recharged by percolation from rain, snow, and seepage from rivers and lakes. Problems are occurring in many parts of the country where groundwater is withdrawn at a faster rate than it is replaced. This overpumping, called mining, results in declining water levels and, in some areas, subsidence, which is the sinking of the land.

Well Construction

Slide 9

Although water utility personnel are seldom involved in the construction of a new well, they are involved in using and maintaining the well. Thus, they should be familiar with the different types of wells and their parts. In addition, water utility personnel should be familiar with the development, testing, disinfection, operation, sanitation, and safety processes involving wells.

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Types of Wells

In the past, wells were dug with a shovel or bucket, bored with an auger, or driven with a drive point. Today, the drilled well is the most common type of well for public water supplies. The drilled well is constructed by the cable tool or rotary drill method.

Parts of a Well

Slide 10

The well casing and cementing protect the well from collapse and surface contamination.The well casing must be made from new carbon steel, high-strength, low-alloy steel, stainless steel, or plastic. It must conform to American Water Works Association (AWWA) standards.

The casing must extend down to the shallowest water-bearing formation. The casing is slipped into the hole and pressure cemented on the outside. Casing and cementing protect the well from collapse and surface contamination. The casing must extend 18 inches above the pump room floor or natural ground elevation (Figure 4.6).

The well screen is a slotted, drilled, or wire-wrapped pipe of corrosion-resistant material such as bronze or stainless steel. The purpose of the well screen is to keep sand out. The mesh size of the well screen opening is determined by the size of the material in the aquifer, the size of the gravel in the gravel pack, and the type of well development. The size of the openings is the most important feature of the well screen.

The gravel pack is made up of fine gravel placed around the well screen to reduce pumping sand. The size varies with the size of the material in the aquifer.

The well vent is a vacuum breaker that allows the casing to breathe as water levels change when the pump cycles and prevents a vacuum from being created. If a vacuum is allowed to form, it could draw contaminants into the well and also restrict the free flow of water to the well pump.

Well Sanitation and Safety

Slide 11

Contamination can come from sewage, industrial wastes, agricultural products, and many other sources.

- Abandoned wells in the area must be sealed.
- Completed wells must be protected by intruder-resistant fences or locked well houses.
- All public water supply wells must be provided with a concrete sealing block, a meter, a screened vent, and a sampling faucet.

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- Before a new well is placed in operation, it must be tested for bacteriological quality. Samples taken on three successive days must be free of coliforms.

Slide 12

- A well head must be properly installed (Figure 4.6).

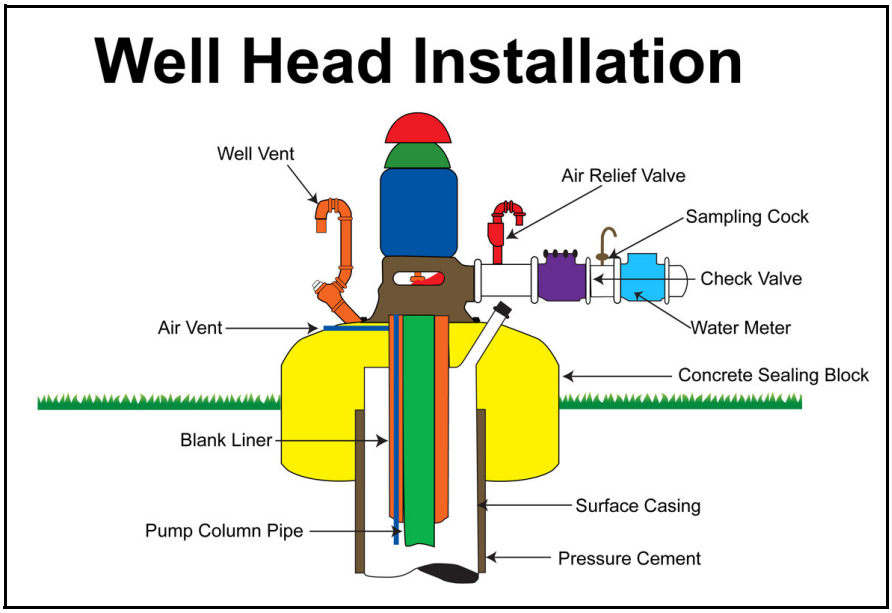

Figure 4.6: Well head installation. *Source: TEEX*

- A sanitary control easement within 150 feet of the well shall be secured from property owners and recorded in the county courthouse deed records.
  - Wells must be a safe distance from wastewater lines, livestock, wastewater pumping stations, animal feed lots, and solid waste sites.
  - No source of contamination shall be within 50 feet of a public well.
  - Call the TCEQ for specific requirements. Figure 4.7 illustrates the safe distances for public wells established by the TCEQ.

Slide 13

Instructor Note

Sanitary control easements are:

- *Legally binding documents securing all land within 150 feet of a public water supply well location from pollution hazards.*
- *Documents must fully describe the location of the well and surrounding lands and must be filed in the county records in order to be legally binding.*

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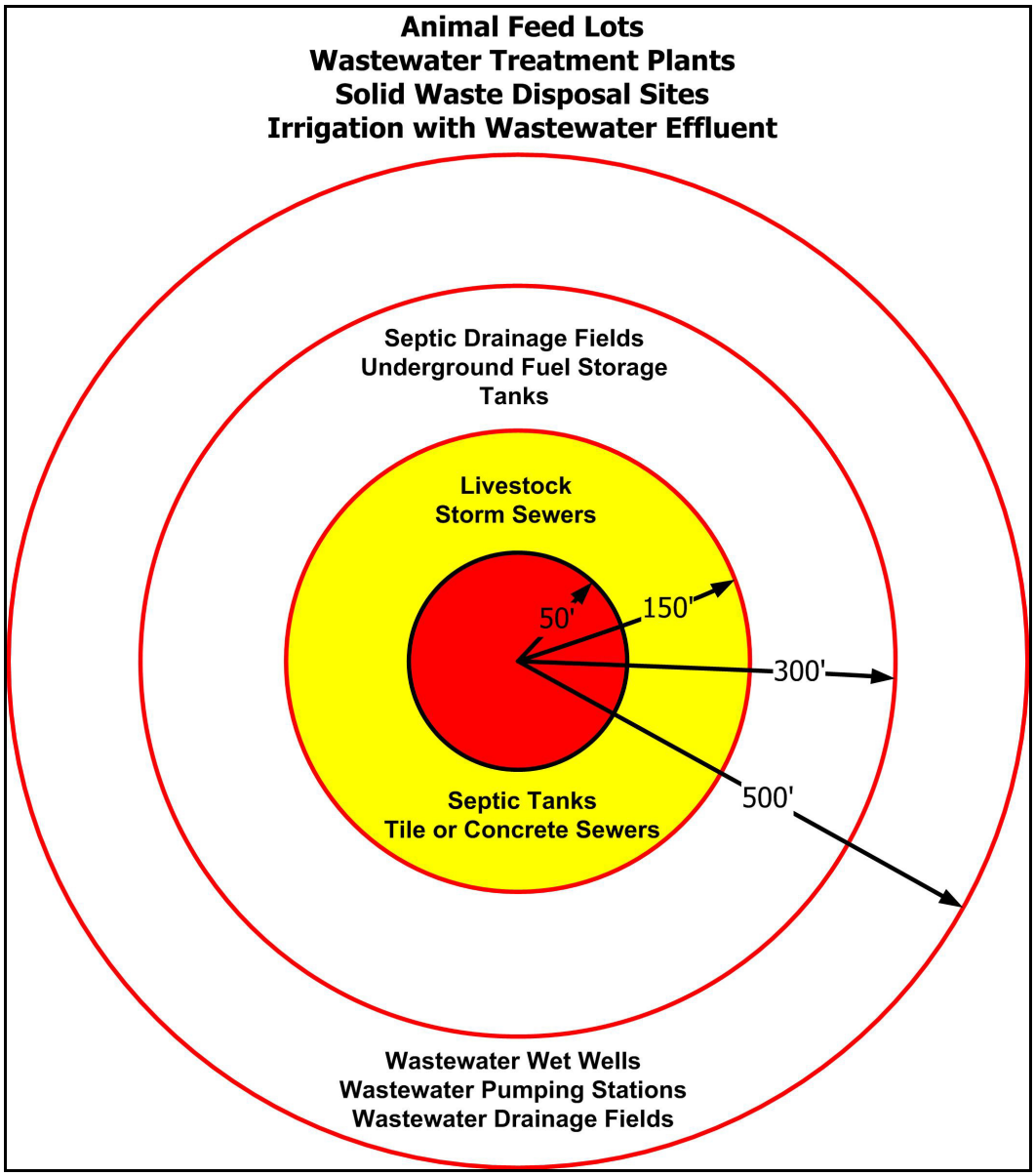

Figure 4.7: Required safe distances from a well. *Source: TEEX*

Developing a Well

After construction, a well must be flushed out to remove drilling mud and loose sand.

Methods such as surging, overpumping, jetting, and backwashing may be used to develop the well. In any case, the pump used for development should not be the same one for permanent use in the well because it will be damaged by the sand and mud.

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Testing

Well contract specifications must include tests and measurements after development. Tests are made over a period of time to provide well and pump efficiency rates and well capacity.

Sand Pumping

Wells can pump considerable amounts of sand. Reasons for sand problems include improper well development, loss of gravel pack, excessively large screen openings or broken screens, corrosion of screen or casing, and overpumping.

Sand pumping can be reduced by the following:

- lowering the gpm pump rate
- cycling the pump less
- installing sand separation devices
- correcting problems such as loss of gravel pack

Disinfecting Wells

Slide 14

After developing and testing, a well must be disinfected with a chlorine dosage of at least 50 mg/L before use. The chlorine must be mixed with the well water and the solution allowed to stand for six hours or more.

The chlorinated water is pumped out and a sample taken for bacteriological analysis. The water cannot be used until samples taken on three successive days show "no coliform organisms found." A sample for physical and chemical analysis must be collected after 36 hours of continuous pumping.

Remember, disinfection is not for the water in the aquifer. Disinfection is for the pump, gravel, and screen.

Instructor Note

Emphasize the Regulatory Requirement:

- *Time*
- *Dosage*
- *Bac-T results*
- *Physical and chemical analysis*

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Well Supply Operation

Slides 15-17

The water level with the pump running is called the pumping level. The water level without the pump running is called the static level. The difference between these two measurements is called the drawdown.

Water levels can be checked with a tape, an airline, or an electric sounder (most accurate). Changes in water levels or the amount of water produced can alert the operator to a drop in the water table, screen stoppage, or damage to the pump.

Pumps and Motors

Slide 18

The most common types of deep well pumps are the submersible and the vertical turbine (Figure 4.8 and Figure 4.9). The vertical turbine is a type of line shaft, centrifugal pump that is water or oil lubricated. A water-lubricated pump requires the bearings to be wet and the water line in operation before starting the pump. Otherwise, immediate damage can result. Shallow wells may use jet pumps when the amount of water to be delivered is small.

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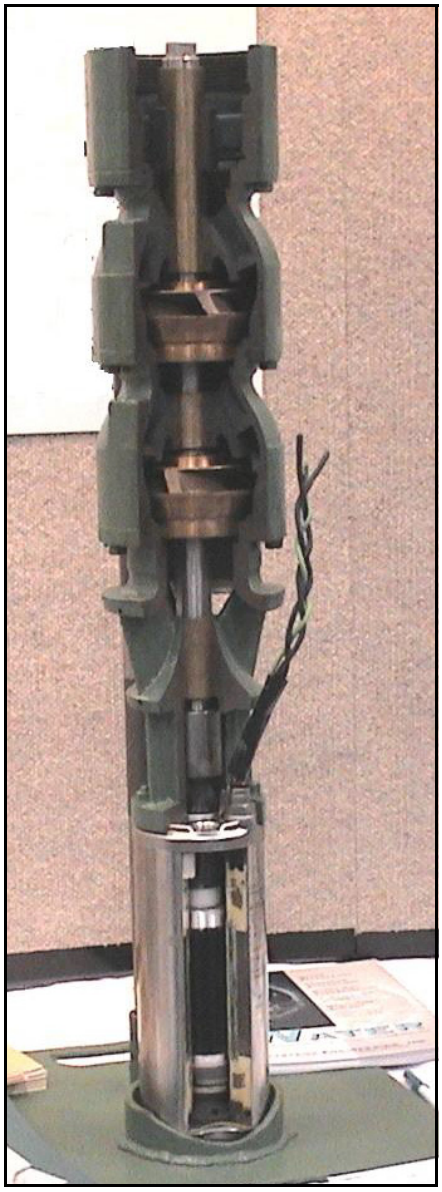

Figure 4.8: Submersible vertical turbine pump.
Source: TEEX

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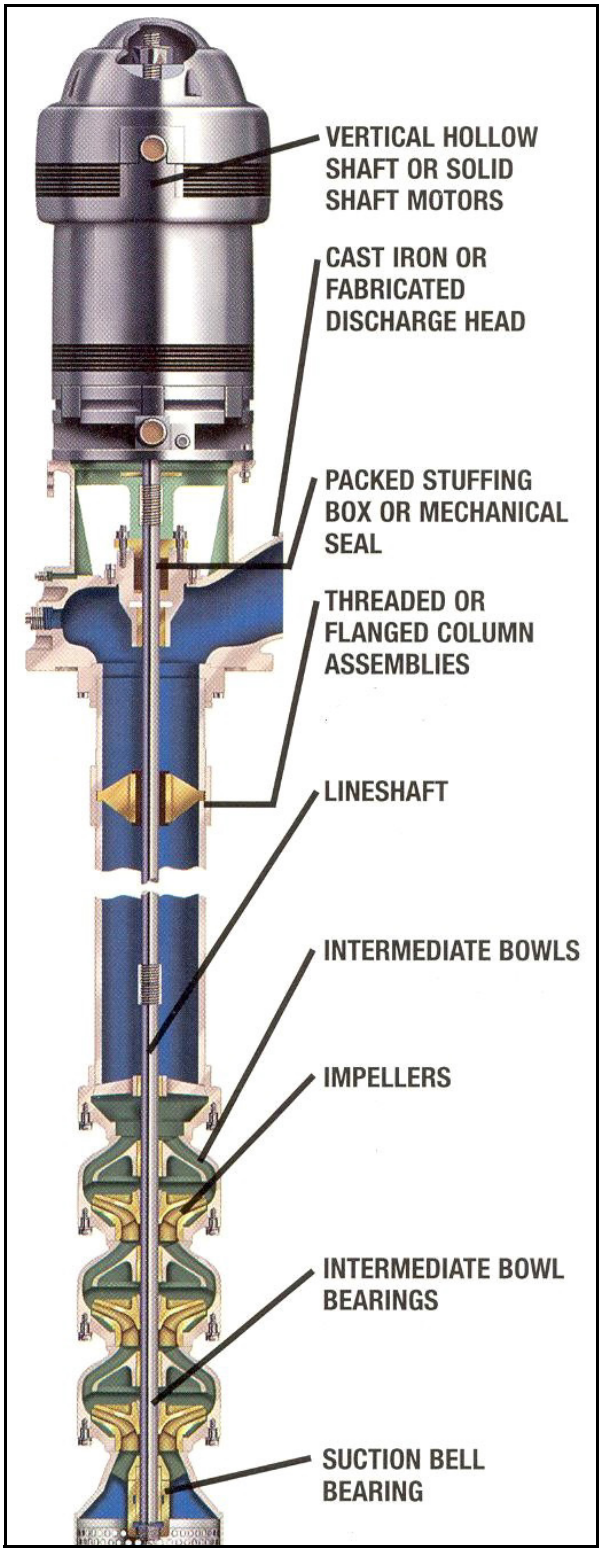

Figure 4.9: Vertical turbine pump.
Source: Layne Christensen, Inc. and ITT-Goulds Pumps.

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Groundwater Treatment

Slide 19

Groundwater is generally wellfiltered and free of turbidity, color, and organic contamination. However, groundwater may be high in minerals, gases, or corrosives. Groundwater may require extensive treatment depending on the impurities present.

Aeration

Aeration is a method that can be used to remove or reduce certain contaminants from water. Cascade aerators, packed air-stripping towers, and air diffusers are used to aerate water.

Gases such as methane, carbon dioxide, and hydrogen sulfide can be reduced by aeration. Hydrogen sulfide, which has a rotten egg odor, is oxidized by super-chlorination. Aeration is also effective in reducing water temperature if the groundwater is hot.

Aeration can also be used to remove iron and manganese from the water supply. Iron levels above 0.3 mg/L cause red stains on clothing, colored water, or turbidity. Excess manganese can cause black stains. Water aerated or chlorinated at proper pH levels oxidizes the iron and manganese, turning them into solid particles. Filtration then removes the particles, producing clear water.

Another method of iron control is the use of sequestering agents such as polyphosphates. Sequestering does not remove iron from the water, but prevents it from combining with oxygen and reddening.

Corrosion Control

Well water is sometimes corrosive. Low pH, dissolved gases, high temperatures, and high mineral levels can cause this. Aeration and pH adjustment with sodium hydroxide or soda ash reduces corrosiveness.

Softening

Softening removes calcium and magnesium by adding lime or by exchanging ions (an atom or group of atoms). Ion exchange replaces calcium ions with sodium ions.

Softening is costly, but ion exchange, demineralizers (a form of ion exchange), and reverse osmosis are used for homes, businesses, or industries.

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Special Treatment Processes

Processes are available for removing arsenic, fluoride, lead, mercury, nitrate, and silver. Coagulation followed by sedimentation and filtration is effective. Reverse osmosis, a process that forces water through a membrane (a sheet of synthetic material) under pressure, is also effective. The membrane prevents passage of dissolved minerals and larger particles, and ejects them in a waste stream.

Surface Water Influence of Wells

Slide 20

Surface Water Treatment Rule

The Surface Water Treatment Rule (SWTR) requires community and non-community wells, springs, and infiltration galleries (a subsurface tunnel that collects groundwater) to determine possible direct influence of surface water.

Changes in groundwater quality can indicate influence of surface water. Surface water organisms such as Giardia cysts, algae, or other microorganisms prove direct influence.

How to Evaluate Surface Water Influence

Procedures for evaluating the influence of surface water on a water supply focus on shifts in water quality such as turbidity, temperature, pH, and the presence of surface water organisms. When shifts in water quality correlate with rainfall or surface water conditions, direct influence by surface water is indicated.

Extensive evaluation is not required if well is:

- deeper than 50 feet and more than 200 feet from a nearby surface water body,
- constructed properly,
- screened or perforated below a confining bed, and
- has no water quality shifts, coliform contamination, or indicated disease outbreaks.

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Summary

Slide 21

This module has provided you with a description of the sources of groundwater. After reading this module, you should have a knowledge of the various attributes of aquifers and the methods for extracting the water from this type of underground source. In addition, you should be able to describe how groundwater is treated and made potable for public use.

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Module 4 Review Questions

1. Aquifers are underground, water-bearing formations yielding useful quantities of water.

   a. **true**

   b. false

2. The quantity of water a formation yields depends on the thickness and permeability of the formation.

   a. **true**

   b. false

3. Problems caused by overpumping are declining water levels and subsidence.

   a. **true**

   b. false

4. Well casing and cementing protect the well from collapse and surface contamination.

   a. **true**

   b. false

5. The purpose of the well screen is to keep out **birds and insects**.

   a. true

   b. **false**

6. The most important feature of the well screen is the **length**.

   a. true

   b. **false**

7. The mesh size of the screen is determined by the size of the aquifer material, the size of the gravel in the gravel pack, and the type of well development.

   a. **true**

   b. false

8. The gravel pack is fine gravel placed around the screen to reduce pumping **bacteria**.

   a. true

   b. **false**

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9. The well vent is a vacuum breaker allowing the casing to breathe as water levels change when the pump cycles.

   a. **true**

   b. false

10. All public wells must be provided with a **steel** sealing block, a meter, a screened vent, and a sampling faucet.

    a. true

    b. **false**

11. No source of contamination is allowed within **500** feet of a public well.

    a. true

    b. **false**

12. One way to reduce sand pumping is to **increase** the pump rate and cycle more.

    a. true

    b. **false**

13. Water from a new well must not be used until bacteriological samples on three successive days show **coliform found**.

    a. true

    b. **false**

14. The water level without the pump running is called the static level, the water level with the pump running is called the pumping level, and the difference between the two is called the **dropdown**.

    a. true

    b. **false**

15. Groundwater usually contains more dissolved minerals and gases than surface water, but fewer _____.

    a. microorganics

    b. **microorganisms**

    c. corrosives

    d. dissolved solids

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16. Water table wells are usually _____ wells.

    a. deep wells

    b. artesian

    c. **shallow**

    d. all listed

17. In a water table well, the cone of depression is a _____ area around the well.

    a. **dewatered**

    b. depressed

    c. deflated

    d. developed

18. A sanitary control easement must cover land within _____ feet of a public well.

    a. 15,000

    b. 1,500

    c. **150**

    d. 15

19. Livestock and septic tanks must be no closer than _____ feet to a public well.

    a. 5,000

    b. 500

    c. **50**

    d. 5

20. Underground fuel tanks and septic drainage fields must be at least _____ feet from a public well.

    a. 15,000

    b. 1,500

    c. **150**

    d. 15

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21. Feedlots, sewage treatment plants, and landfills must be at least _____ feet from a public well.

    a. 50

    b. **500**

    c. 5,000

    d. 50,000

22. A well may be developed by surging, overpumping, jetting, and _____.

    a. **backwashing**

    b. backflushing

    c. backflooding

    d. backfilling

23. To disinfect a new well, a chlorine dosage of at least _____ mg/L of chlorine is required.

    a. 5

    a. 10

    b. 25

    c. **50**

24. A sample for physical and chemical analysis must be taken after _____ hours of pumping.

    a. 3

    b. 6

    c. **36**

    d. 63

25. Changes in well water levels or the volume of water produced can alert the operator to a drop in the water table, screen stoppage, or damage to the _____.

    a. sealing block

    b. **pump**

    c. vent

    d. sampling faucet

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26. Common deep well pumps include the _____ and the vertical turbine.
    a. submarine
    b. subsidence
    c. submission
    d. **submersible**

27. Gases such as methane, carbon dioxide, and hydrogen sulfide are reduced by _____.
    a. backwashing
    b. sequestering
    c. **aeration**
    d. softening

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Module 4 Presentation Slides

Basic Water Operations

Module 4
Groundwater Production

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Terminal Objective

Upon successful completion of this module, the participant will be able to describe how ground water is made usable.

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Enabling Objectives

- Discuss the relationship of aquifers to types of wells.
- Discuss common methods of groundwater treatment.

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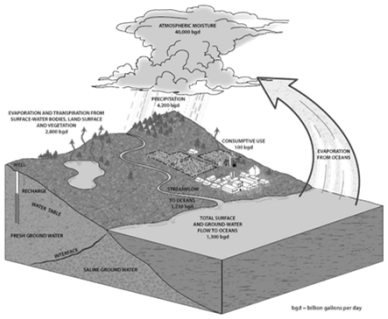
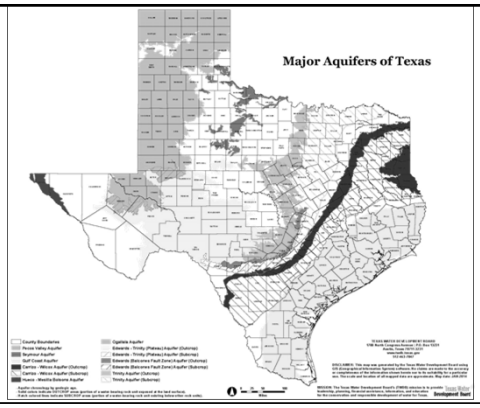
Sources of Groundwater



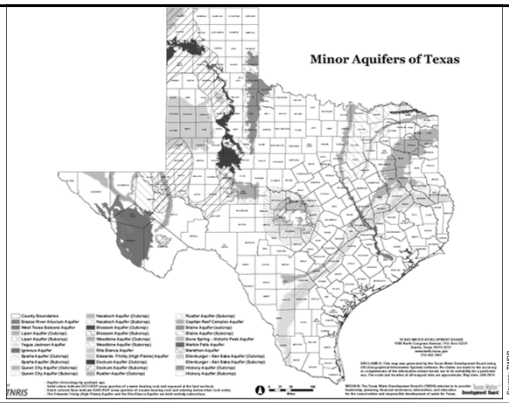
Source: USGS

Major Aquifers of Texas



Source: TWDB

Minor Aquifers of Texas



Source: TWDB

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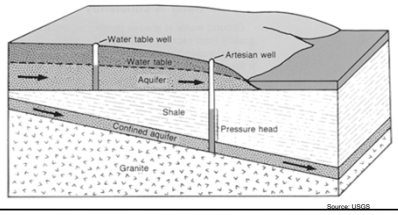
Groundwater Withdrawal

- **Springs**
- **Water Table Wells**
- **Artesian Wells**



Source: USGS

Groundwater Recharge

- Aquifers recharged by percolation
  - Rain/snow
  - Seepage from lakes and rivers
- Overpumping is a problem

Wells

- Construction
- Types
  - Dug with shovel/bucket
  - Bored with auger
  - Driven with a drive point
  - Drilled well is most common

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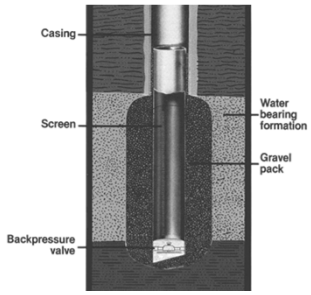
Parts Of A Well



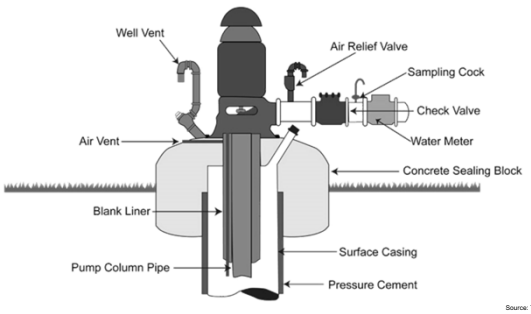
- **Casing**
- **Well Screen**
- **Gravel Pack**
- **Well Vent**

Source:

Well Sanitation and Safety

- Seal abandoned wells
- Protect with fences or locked well house
- Sealing block, meter, vent, sampling faucet
- Test bacteriological quality
- Secure sanitary control easement

Well Head Installation



Source: TEEX

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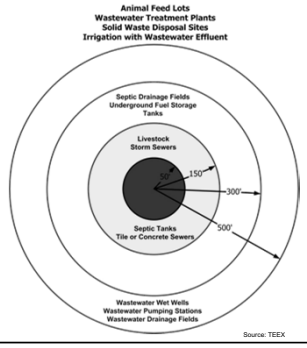
Safe Distances From Well

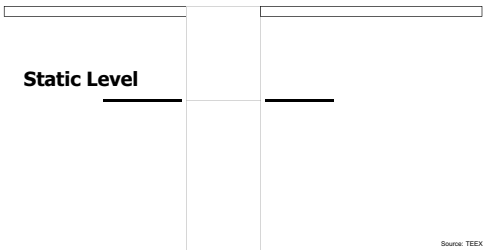


Source: TEEX

Disinfecting Wells

- Disinfect before use
- Chlorine dosage of at least 50 mg/L
- Allow to stand for 6+ hours
- Take bacteriological sample
- Three samples show no coliform organisms
- Physical, chemical analysis after 36 hours

Well Supply Terminology



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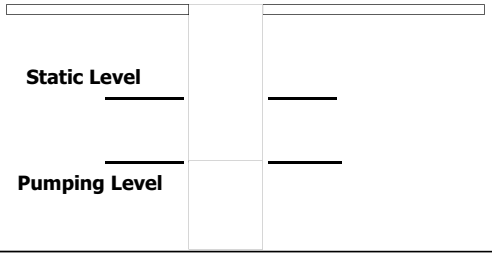
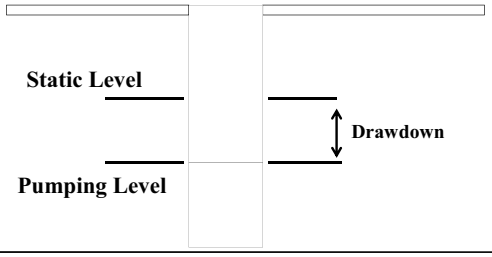
Well Supply Terminology

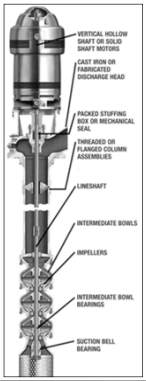


Well Supply Terminology



Pumps

- Submersible
- Vertical turbine
- Series pumps


VERTICAL HOLLOW SHAFT OR SOLID SHAFT MOTORS
CAST IRON OR FABRICATED DISCHARGE HEAD
PACKED STUFFING BOX OR MECHANICAL SEAL
THREADED OR FLANGED COLUMN ASSEMBLIES
LINESHAFT
INTERMEDIATE BOWLS
IMPELLERS
INTERMEDIATE BOWL BEARINGS
SUCTION BELL BEARING
Source: Layne-Christensen, Inc. and ITT-Goulds Pumps

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Groundwater Treatment

- Aeration
- Corrosion Control
- Softening
- Special Processes
  - Coagulation/Sedimentation
  - Reverse Osmosis

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Surface Water Influence

- GUI – Under direct influence
- Impact on shallow/at-risk wells
- SWTR
- Identify risk of Giardia/others
- Evaluation of surface water influence

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Module 4

Review Questions

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End of Module 4

Next Module:
Surface Water Production

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Module

5

Surface Water Production

Terminal Objective

Upon the successful completion of this module, the participant will be able to describe how surface water is made usable.

Enabling Objectives

1. List the major Texas regulations that govern surface water.
2. Describe the surface water treatment process.
3. Explain surface water treatment rules.

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Instructional Guidance

Time

2 hours, 50 minutes

Materials/Equipment

1. Participant manual
2. Laptop with presentation slides for module 5
3. Internet connectivity
4. Video/data projector
5. Screen or monitor

Instructor Preparation

Prepare projector and position first presentation slide.

Application of Participants' Knowledge/Skills

Ask participants to complete the review questions at the end of the module and allow them ample time.

Evaluation of Participants

Go over the review questions at the end of the module, answering any questions the participant may still have.

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Introduction

Slides 1-3

Rivers, lakes, and reservoirs are surface water sources, and are broadly grouped into the following three categories:

- Rivers
- Natural lakes
- Man-made lakes

Slide 4

Texas has 23 major river basins, according to TWDB, with the Rio Grande being the longest, running 1,250 miles along the Mexico border (Figure 5.1). The U.S. Geological Survey identifies about 3,700 Texas streams. The combined length of these streams is about 80,000 miles and drain 263,513 square miles within Texas.

This module provides an overview of surface water production. State regulations and the treatment required to change surface water to quality water will be discussed.

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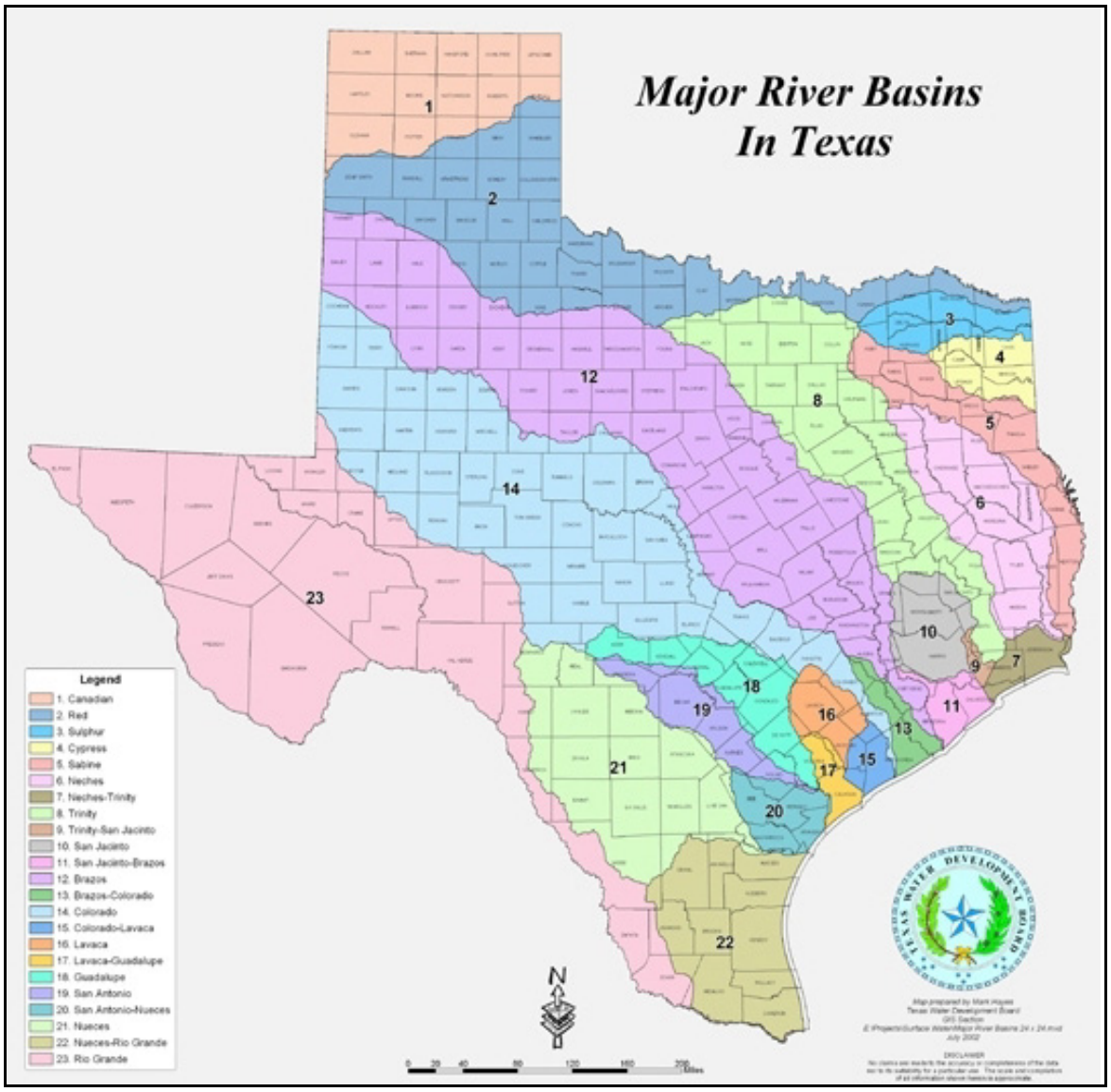

Figure 5.1: Major river basins. *Source: Texas Water Development Board*.

Sources of Surface Water

Texas has 204 major reservoirs and more are planned. A major reservoir contains at least 5,000 acre-feet. One acre-foot is an acre by one foot deep and equals 325,851 gallons.

All major reservoirs in Texas are man-made except Caddo Lake, which is located on the Texas-Louisiana border 30 miles northeast of Marshall. The largest reservoir within Texas is Sam Rayburn, located about 30 miles east of Lufkin.

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Only 40% of public water systems use surface water, but they serve 3/4 of the population. Therefore, large cities tend to use surface water. San Antonio, the third largest city in Texas, is an exception. San Antonio uses groundwater from the Edwards aquifer.

Protecting Surface Sources

Slide 5

Bacteria, algae, and chemicals are common contaminants of surface water. Contamination comes from sewage treatment plant effluent, seepage from septic tank drainfields, and runoff from agricultural areas containing pesticides and fertilizers.

Slide 6

Water utility operators can control contamination by inspecting watersheds regularly, controlling erosion to reduce river silt, controlling algae, fencing reservoirs when possible, and marking water treatment plant intakes with buoys.

State Regulation of Surface Water

Slide 7

In Texas, the TCEQ has established the following regulations:

- Shore installations, marinas, boats, and houses on the watershed must have sewage disposal.
- Septic tanks, absorption fields, sewers, manholes, or toilets cannot be within 75 feet of a lake at spillway elevation or the 50-year flood elevation.
- Plant intakes shall have screens and grates to minimize the amount of debris entering the plant.
- No boat ramps, marinas, docks, or fishing piers can be within 1,000 feet of an intake.
- All activities shall be restricted within 200 feet of an intake.

Treatment of Surface Water

Water from large lakes may be low in bacteria and organic matter while river water can be high in bacteria and other contaminants. Most surface water is low in minerals, gases, and dissolved solids, but turbidity and algae are common problems.

Objectives of Surface Water Treatment

Slide 8

To protect the health of the community, treated water must be free of disease-causing organisms and harmful chemicals must be reduced to safe levels.

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To supply an aesthetically pleasing product, water must be low in color, turbidity, suspended solids, temperature, and free of taste and odor.

To protect consumer property, water should not be corrosive, deposit scale, or stain plumbing. Colored water can be caused by organics, algae, iron, or manganese.

Slide 9

Because characteristics of water sources may vary greatly, the following are indicated properties of quality water:

- An absence of harmful chemicals
- An absence of disease-causing organisms
- Little or no color, turbidity, solids, odor, or taste
- Noncorrosive, nonstaining, and non-scale forming

Required Treatment

Slides 10-12

Treatment can include aeration, screening, chemical oxidation, coagulation, flocculation, sedimentation, filtration, and disinfection. Treatment required by the TCEQ (290.42(d)(1) for all surface water includes the following:

- Pretreatment disinfection
- Taste and odor control
- Coagulation
- Sedimentation
- Filtration
- Terminal disinfection
- Covered storage (clear well storage)

Pretreatment Processes

Slide 13

Surface water is pretreated to remove taste and odor or contaminants such as turbidity. Pretreatment removes materials that affect treatment methods. Pretreatment includes:

- reservoir destratification,
- control of algae,
- debris removal,
- presedimentation,
- aeration,

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- chemical oxidation, and
- activated carbon adsorption.

Reservoir Destratification

Slide 13

Deep reservoirs become stratified by temperature differences where cold water is trapped below warmer water. Stratified reservoirs can have problems with algae, iron and manganese, and hydrogen sulfide. Injection of air at the bottom of the reservoir (from spring to fall) will result in mixing to destratify the lake.

Chemical Control of Algae

With enough sunlight and nutrients, algae can bloom in a reservoir, causing taste and odor problems and affecting chemical and biological changes in water quality. Using copper sulfate at dosages of 0.1 to 0.5 mg/L and approved algaecides will assist in controlling algae blooms.

Debris Removal

Screening at the raw water intake prevents debris from damaging pumps or blocking transmission lines. Screens can be manually or mechanically cleaned.

Presedimentation

Rivers or shallow reservoirs can have heavy silt loads during high flows or rainfall. Presedimentation in reservoirs or sedimentation basins are effective in reducing turbidity.

Slide 14

Aeration

Aeration is the incorporation of air into the water by means of spray nozzles, steps or cascades, or trays or diffusers.

Aeration removes tastes, odors, certain organics and gases, and oxidizes iron and manganese.

Chemical Oxidation

Chemical oxidation destroys microorganisms and assists in reducing taste and odor problems. Chemical oxidants commonly used are chlorine, potassium permanganate, chlorine dioxide, and ozone. These oxidants may also kill algae, oxidize iron and manganese, and reduce organic chemicals.

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Activated Carbon Adsorption

Slide 14

Bacteria or algae are a major cause of taste and odor problems. The most effective treatment is adsorption utilizing activated carbon. Carbon is applied at the raw water pumping station or in the rapid mix. The surface structure of activated carbon will trap and hold organic material. Sedimentation and filtration remove the carbon and its bonded organics.

Chemical Treatment Processes

Chemical Addition

Slide 15

Chemical feeders meter and add chemicals at a uniform rate (Table 5.1). Dry chemicals can be added gravimetrically, volumetrically, or in solution. Temperatures affect the rate of chemical reaction. The higher the temperature, the faster the reaction. Temperature will also affect mixing and flow patterns.

Chemical pump feedrate is determined by measuring the solution withdrawn from a marked cylinder over time. The volume dispensed in one minute can be compared to the desired rate, and the pump adjusted accordingly.

Table 5.1: Chemicals Commonly Used in Water Treatment

Name	Purpose
Sodium aluminate	Coagulant
Aluminum sulfate (alum)	Coagulant
Ferrous sulfate	Coagulant
Ferric chloride	Coagulant
Calcium hydroxide (lime)	pH adjustment, softening, aid to coagulation
Sodium carbonate (soda ash)	Softening, removal of heavy metals, aid to coagulation, pH and alkalinity adjustment
Polyphosphates (calgon)	Stabilization, prevents red water
Copper sulfate (blue stone)	Algae control
Polyelectrolytes	Aid to coagulation
Activated silica	Aid to coagulation
Activated carbon	Removal of tastes, odor, organics
Fluorosilic acid, Sodium silicofluoride, Sodium fluoride	Fluoride addition, prevents tooth decay

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Slide 16

Coagulation and Flocculation

The processes of chemical mixing, coagulation, flocculation, and sedimentation remove suspended and dissolved materials from water. These processes are commonly used for surface water, but can be used to remove hardness or iron in groundwater.

First, chemicals are mixed with the water in a rapid mix zone. The chemicals cause particles in the water to coagulate and to form floc. Then, the water passes into a tank where mixers slowly agitate the water. This process, known as flocculation, causes the floc to form larger particles that will settle more readily.

Common coagulating chemicals are alum, ferrous sulfate, and ferric chloride. Lime or soda ash raise or lower the pH and polymers are used to enhance the coagulation and flocculation. Jar tests assist the operator in determining which chemical, and how much, to apply. Turbidity, pH, temperature, alkalinity, and chemical dosage affect coagulation.

The amount and characteristics of suspended materials in raw water will influence coagulation. For example, highly turbid waters, where the turbidity is heavy, generally require less coagulant due to the increase in interparticle collisions.

Very low turbidity waters, however, where the turbidity is of a colloidal nature, are difficult to coagulate. Very finely suspended solids (turbidity) will require increased coagulant dosages.

The pH of the water to be coagulated is perhaps the single most important factor in effective coagulation. Each coagulant has an optimum pH range in which the best coagulation takes place. Failure to operate within optimum pH range for given water may waste chemicals and result in a poor quality effluent.

Usually, the colder the water, the slower the chemical reaction of coagulation. As temperature decreases, the viscosity of the water increases and the rate of floc settling is decreased.

The alkalinity of water is its quantitative capacity to neutralize a strong acid to a designated pH. The test provides results used in calculating the chemical dosages needed in coagulation and softening processes.

Slide 17

Chemical dosages will be determined by a series of jar tests. The chemical dosage should be such that no concentrations over 10 NTU, preferably as low as 5 NTU, shall go onto the filter (Figure 5.2).

If coagulation and flocculation are conducted properly, the sedimentation and filtration that follow will reduce suspended solids and colloidal materials (turbidity) to very low levels.

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Slide 18

Jar testing is a device used to determine the effectiveness of chemical coagulation of water that can be experimentally evaluated in the laboratory (Figure 5.2). The jar tester usually has six paddles that have the ability to adjust the revolution from 0 to 100 rpms. In making the test, one liter or more is placed in each jar. While stirring at around 80 to 100 rpms a chemical coagulant is added and mixed for approximately one minute, reduced to 25 to 30 rpms for 20 to 30 minutes, and then turned off.

The operator then observes the characteristics of the floc as it settles. A hazy sample indicates poor coagulation, while proper coagulation indicates a well-formed floc that settles, leaving a clear liquid. The lowest dosage that provides a good turbidity removal during the jar test is considered the first trial dosage in plant operation. A full-scale coagulation and flocculation process can be conducted for a wide range of conditions.

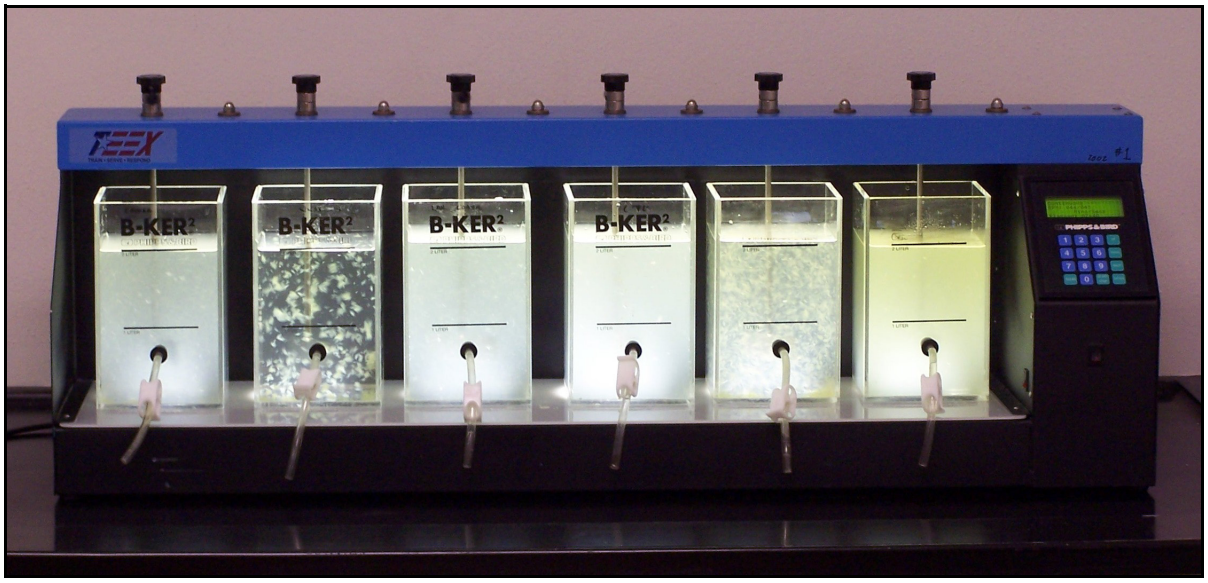

Figure 5.2: Jar sequence test. *Source: TEEX.*

Coagulation and flocculation are sensitive to many variables, such as the nature of the turbidity-producing substances, type and dosage of coagulant, pH of the water, temperature and viscosity of the water, alkalinity and hardness, and other variables. The purpose of running variations in mixing, dosages, and settling rates is help produce a floc that is resistant to shear and breakup during flocculation as it moves through the train or stages. The TCEQ considers a maximum turbidity of 10 NTUs as acceptable going onto the filter; 5 NTUs is good and 2 or fewer is optimized, producing a filter effluent of 0.1 NTU.

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Sedimentation

Slide 19

After the floc forms, the water flows into a sedimentation basin. This basin allows the water to settle to a quiet state. A detention time of at least six hours is required to allow the floc to settle. The settled floc, called sludge, is removed from the basin periodically.

Sedimentation is accomplished in either square, rectangular, or circular tanks. Sludge blanket clarifiers (upflow clarifiers) mix, coagulate, flocculate, and settle in the same unit. The flow rises through the sludge blanket, encouraging filtering and settling. Zones in a settling tank include the inlet, outlet, settling, and sludge zones.

Factors influencing sedimentation include:

- floc size and shape—floc is too large and has poor settling qualities;
- water temperature—the colder the water temperature, the greater the density and the more resistant to floc setting;
- floc-specific gravity—the heavier the floc, the better it settles. Floc that is too heavy may settle too rapidly, leaving colloidal matter in suspension;
- detention time—the basin volume must provide at least six hours detention time;
- velocity—volume and tank shape must maintain velocities of 0.01 to 0.03 feet per second; and
- short-circuiting—short-circuiting shortens detention time and increases water velocity.

Sludge Disposal

Slide 20

Thick sludge blankets must not be allowed to form in sedimentation basins because they could:

- create taste and odor problems;
- reduce the capacity of the settling tank;
- form gas and cause floating solids; or
- change the chemical quality of the water.

Sludge is disposed of in lagoons, discharged into sanitary sewers, or dewatered and hauled to sanitary landfills.

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Filtration

Slides 21-22

If coagulation, flocculation, and sedimentation are effective, filtering will remove remaining suspended solids and pathogens such as Giardia and Cryptosporidium, which are chlorine resistant. Filtration is the final step in removing suspended matter and chlorine-resistant microorganisms (Figure 5.3).

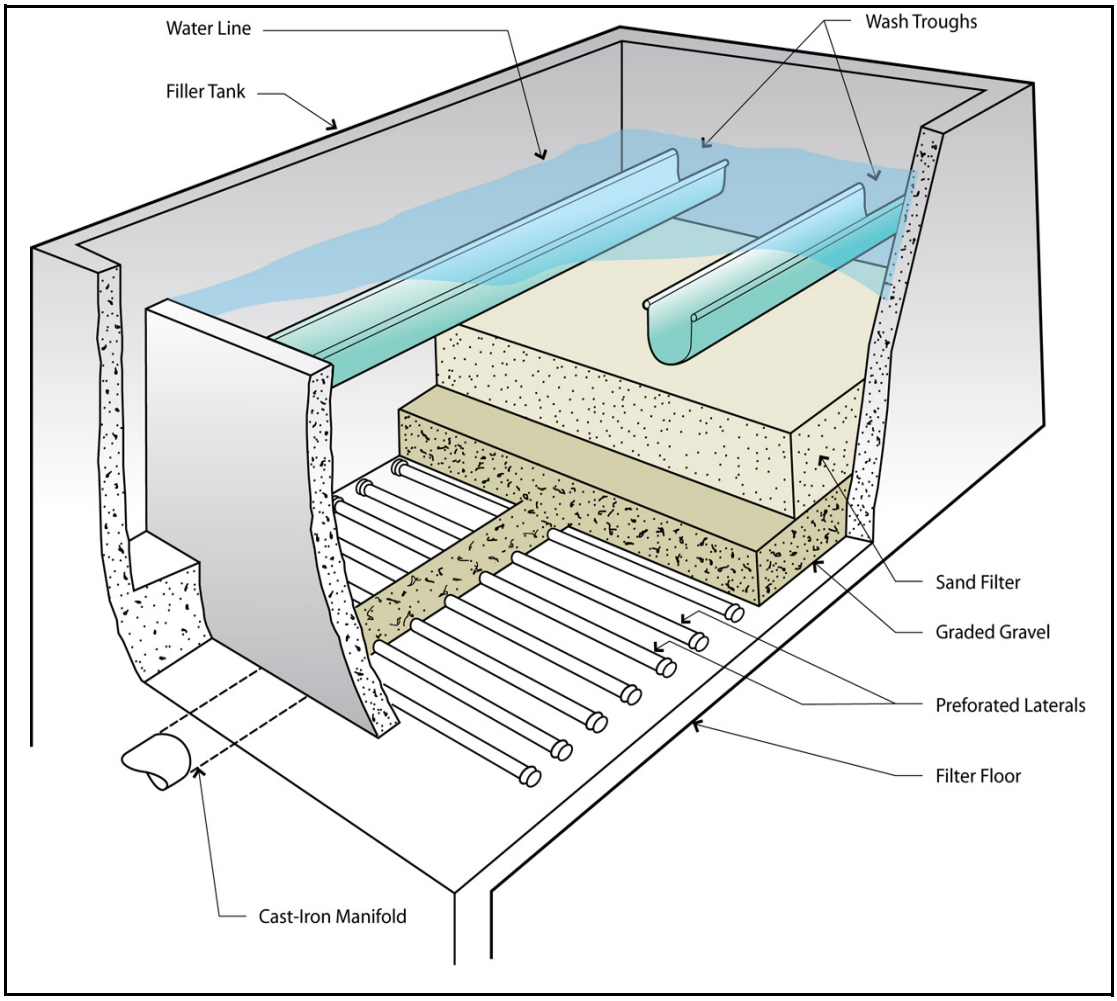

Figure 5.3: Sand filter. *Source: TEEX.*

A filter has 24 to 30 inches of porous material such as sand or anthracite coal, called filter media. The filter bottom and gravel support the filter media. A common filter is the rapid sand filter, which has several layers of differently sized media. These units filter 2 gallons per minute per square foot of filter media.

The parts of a rapid sand filter are as follows:

- Filter box
- Wash water troughs

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- Inlets and outlets
- Underdrains
- Valves and piping
- Filter agitators (surface wash)
- Loss-of-head gauge
- Rate-of-flow controllers

Slide 23

As water percolates through the media, the filter will gather solids (Figure 5.4). As the solids increase, there will be a loss of head (pressure) through the filter due to increased friction. When this head loss is about 6 to 10 feet, the filter must be backwashed. Operators may use other criteria such as filter effluent turbidity or length of filter time to decide when to backwash.

Instructor Note

Facilitate a discussion on the average life of a filter at participants' facilities. This allows participants to share their experiences, problems, and solutions when working with filters.

While the backwash is taking place, the filter bed should expand 30% to 50% to ensure good scouring action. If backwashing is done improperly, mud balls form in the media, causing it to crack and clog up. Pressure sand filters have the media and underdrains enclosed in a steel tank. The media is similar to that in gravity sand filters. Filtration rates range from 2 to 4 gallons per minute per square foot of filter media. The state requires pressure filters to operate at 2 gpm per square foot.

Pressure filters are used in small systems, swimming pools, and industrial plants. Pressure filter media is not easily inspected and problems may go uncorrected.

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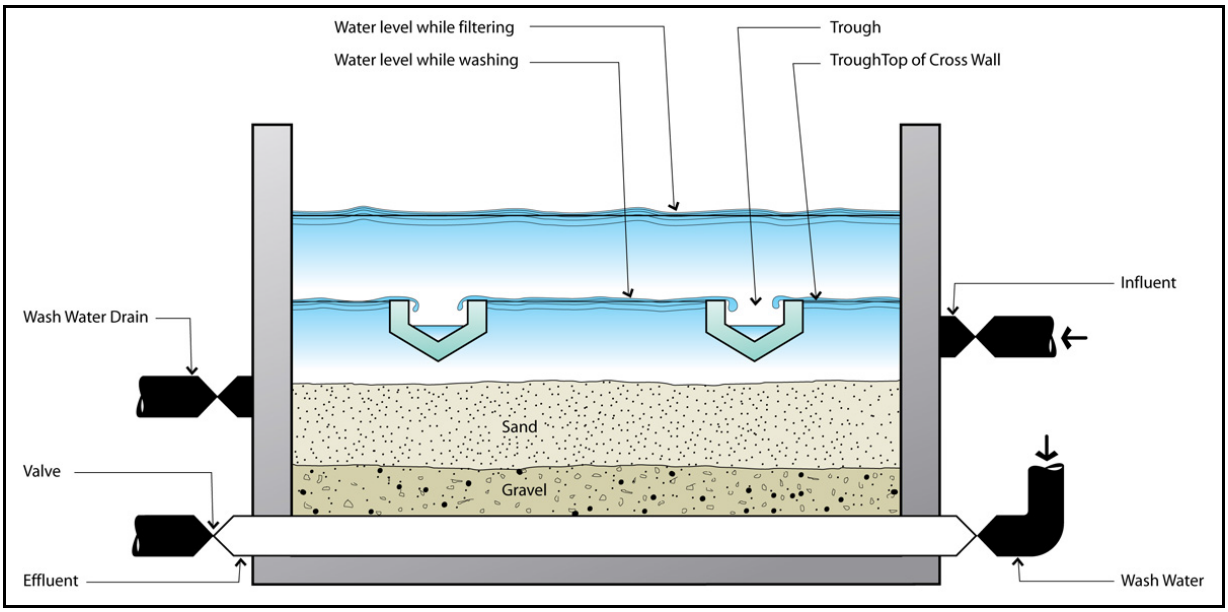

Figure 5.4: Sand filter cutaway. *Source: TEEX.*

Filter problems may involve the following:

- Mud balls, which clog a filter
- Cracks and channeling, which allow bypassing of the filtering action
- Damaged underdrains, causing poor filtering and backwash
- Air collected in the underdrains and media (air-binding) that leads to damage during backwashing

Disinfection of Surface Water

Slide 24

Because surface water is likely to contain pathogens along with turbidity, which can harbor pathogens, adequate disinfection is critical. Disinfection is the process of destroying or inactivating pathogenic agents. The TCEQ requires the following:

- Disinfection of surface water prior to storage
- Facilities for pretreatment disinfection and terminal disinfection
- Standby disinfecting equipment and excess capacity (50% greater than the highest expected dosage)

Chemicals used to disinfect include chloramine, chlorine, chlorine dioxide, and ozone. Chlorination of surface water may lead to the formation of trihalomethanes and haloacetic acids. To avoid these, chloramine, ozone, or chlorine dioxide may be used for pretreatment disinfection and chloramine for post-disinfection.

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Clear Well Storage

Treated water is stored at the plant in the clear well. The clear well provides detention time for disinfection and extra storage.

Surface Water Treatment Rules

Turbidity

Slide 25

A system's filtered water must be less than or equal to 0.3 Nephlometric Turbidity Units (NTU) in at least 95% of the measurements taken each month, and no sample can exceed one NTU. Systems serving less than 500 persons may reduce turbidity sampling to once per day (Table 5.2).

Disinfection

The combination of treatment and disinfection must achieve at least 99.9% inactivation/removal of Giardia lamblia cysts and at least 99.99% inactivation/removal of viruses. The filtered water must be continuously monitored for adequate disinfection levels. Inadequate disinfection must be reported to the state the next business day.

The disinfection residual must be measured at the same points and times in the distribution system as total coliform sampling. No more than 5% of the distribution samples can have inadequate residuals for two consecutive months.

Systems serving 3,300 or fewer persons can take grab samples in lieu of continuous disinfection monitoring at the frequencies indicated in Table 5.2.

Table 5.2: Chlorine Monitoring Frequencies

System Population	Chlorine Residual Samples Per Day
<500	1
501–1,000	2
1,001–2,500	3
2,501–3,300	4

Tracer Studies

To assess the adequacy of disinfection contact time, tracer study data must be submitted to the state.

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When Surface Water Influences Well Water

Slide 25

Wells less than 50 feet in depth and wells in limestone formations and springs must be evaluated for surface water organisms and debris. Sources exhibiting surface water contamination are required to install treatment. Minimum treatment is coagulant addition, filtration, clearwell storage, plus surface water disinfection and monitoring requirements already noted.

Fluoridation

Fluoride in drinking water is beneficial or detrimental depending on the amount present. Studies indicate moderate levels of fluoride (0.7 to 1.0 mg/L) reduce cavities and dental care costs. Waters high in natural fluoride (above 2.0 mg/L) cause mottling (a brown stain) of the enamel.

Sodium fluoride, sodium silicofluoride, and fluorosilic acid are fluoride compounds added to water supplies. These compounds are fed in controlled amounts by chemical pumps as the water goes to storage.

Excessive fluoride is reduced by activated alumina contact beds, demineralizers, reverse osmosis, and other methods. These are expensive techniques and are rarely used.

Summary

Slide 26

Treated surface water becomes drinking water after a lengthy process governed by state regulatory agencies. In the next module, we will discuss the disinfection of water.

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Module 5 Review Questions

1. Water from rivers, lakes, and reservoirs is called **groundwater**.

   a. true

   b. **false**

2. **Fifty** percent of public water systems use surface water.

   a. true

   b. **false**

3. Boat ramps, marinas, and docks should not be located within 1,000 feet of a water intake.

   a. **true**

   b. false

4. Surface water contains bacteria, algae, and turbidity, but is low in minerals, gases, and dissolved solids.

   a. **true**

   b. false

5. The objectives of water treatment are protecting of public health, supplying an aesthetically pleasing product, and protecting consumer property.

   a. **true**

   b. false

6. The TCEQ requires surface water to have pretreatment, pre-disinfection, taste and odor control, coagulation, sedimentation, filtration, covered storage, and terminal disinfection.

   a. **true**

   b. false

7. Methods for controlling taste and odor problems are lake destratification, algae control, aeration, chemical oxidation, and activated carbon.

   a. **true**

   b. false

8. One of the causes of taste and odor problems is algae and bacteria.

   a. **true**

   b. false

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9. Coagulants are sodium aluminate, aluminum sulfate, ferrous sulfate, and **sodium chloride**.

   a. true

   b. **false**

10. Coagulants cause small particles in water to clot together forming floc, and this process, flocculation, forms larger particles that settle more readily.

    a. **true**

    b. false

11. **Bucket** tests help the operator determine the chemical and dosage to apply.

    a. true

    b. **false**

12. Turbidity, pH, temperature, alkalinity, and chemical dosage affect coagulation.

    a. **true**

    b. false

13. To remove suspended solids and chlorine-resistant microorganisms, surface water must be **disinfected**.

    a. true

    b. **false**

14. Filtering is the final step in removing suspended matter and chlorine-resistant microorganisms.

    a. **true**

    b. false

15. A common filter is the **slow** sand filter, having several layers of differently sized media.

    a. true

    b. **false**

16. A filter must be **whitewashed** when a head loss of 6 to 10 feet occurs.

    a. true

    b. **false**

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17. Most surface water is low in minerals, gases, and _____.

    a. algae

    b. turbidity

    c. **dissolved solids**

    d. bacteria

18. Quality water has low amounts of color, turbidity, solids, and _____.

    a. oxygen

    b. **taste and odor**

    c. hydrogen

    d. all listed

19. Pretreatment includes lake destratification, control of algae, debris removal, presedimentation, aeration, _____, and activated carbon adsorption.

    a. **chemical oxidation**

    b. filtration

    c. terminal disinfection

    d. backwashing

20. Copper sulfate in dosages of _____ and approved algaecides control algae blooms.

    a. 10 to 50 mg/L

    b. 1 to 5 mg/L

    c. **0.1 to 0.5 mg/L**

    d. 0.01 to 0.05 mg/L

21. The most effective treatment for taste and odor is adsorption with _____.

    a. **activated carbon**

    b. chlorine

    c. ferric chloride

    d. copper sulfate

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22. Lime is applied to water to _____.

    a. coat water mains

    b. **adjust pH or alkalinity**

    c. prevent tooth decay

    d. prevent algae

23. The process of using chemicals to clot particles together is called _____.

    a. sedimentation

    b. filtration

    c. **coagulation and flocculation**

    d. all listed

24. Detention time in sedimentation basins must be at least _____ hours to allow floc to settle.

    a. **six**

    b. five

    c. four

    d. three

25. Factors affecting sedimentation are weight of the floc, _____, detention time, and short-circuiting.

    a. water temperature

    b. water velocity

    c. taste and odor

    d. **a and b**

26. Backwashing should expand the filter bed by _____%.

    a. 5 to 10

    b. 15 to 20

    c. 25 to 30

    d. **30 to 50**

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27. A common filter problem is _____, prevented by proper backwashing.

    a. ice

    b. **mud balls**

    c. detention time

    d. coagulation

28. Chemicals used in disinfection are chloramine, chlorine, chlorine dioxide, and _____.

    a. ferrous sulfate

    b. copper sulfate

    c. activated carbon

    d. **ozone**

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Module 5 Presentation Slides

Basic Water Operations

Module 5
Surface Water Production

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Terminal Objective

Upon successful completion of this module, the participant will be able to describe how surface water is made usable.

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Enabling Objectives

- List the major Texas regulations that govern surface water.
- Describe the surface water treatment process.
- Discuss surface water treatment rules.

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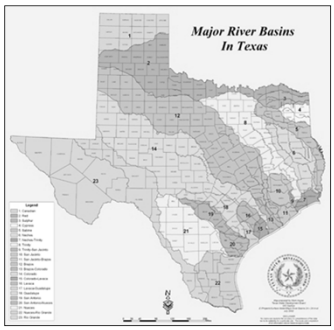
Sources of Surface Water



- **23 major river basins**
- **Natural lakes**
- **Man-made lakes**

Protecting Surface Sources

- Common contaminants
  - Bacteria
  - Algae
  - Chemicals
- Sources
  - Sewage plant effluent
  - Septic tank drain fields

Protecting Surface Sources

- Contamination control
  - Inspect watersheds regularly
  - Control erosion to reduce river silt
  - Control algae
  - Fence reservoirs when possible
  - Mark treatment plant intakes with buoys

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State Regulation of Surface Water

- Shoreline installations must have sewage disposal
- Disposal not within 75 ft. of intake
- Disposal not within 50-year flood elevation
- Screens and grates on plant intakes
- Activities restricted within 200 ft. of intake

Objectives of Surface Water Treatment

- Protect the health of the community
- Supply an aesthetically pleasing product
- Provide quality water to consumer
- Protect consumer property

Properties of Quality Water

- Absence of harmful chemicals
- Absence of disease-causing organisms
- Little or no color, turbidity, solids, odor, and taste
- Noncorrosive and nonstaining

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Required Treatment

- Aeration
- Screening
- Chemical oxidation
- Coagulation
- Flocculation

Required Treatment

- Sedimentation
- Filtration
- Disinfection

TCEQ Required Treatment

- Pretreatment
- Taste and odor control
- Coagulation
- Sedimentation/filtration
- Covered storage
- Terminal disinfection

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Pretreatment Processes

- Reservoir destratification
- Chemical control of algae
- Debris removal
- Presedimentation

Pretreatment Processes

- Aeration
- Chemical oxidation
- Activated carbon adsorption

Chemical Treatment

- Use of chemical meters
- Dry chemicals
- Temperatures and chemical reaction
- Chemicals used (Table 5.1)

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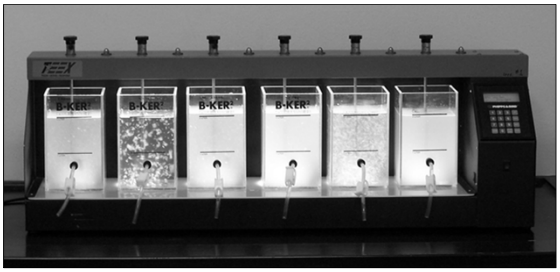
Chemical Treatment

- Coagulation/flocculation
  - Removes materials from water
  - Commonly used for surface water
  - Chemicals/water mix in rapid mix zone
  - Floc forms and passes to next tank
  - Larger floc forms and settles

Jar Test Sequence



Source: TEEX

Chemical Treatment

- Jar test determines chemical application
- pH adjustment can be made
  - Lime/soda ash raises/lowers pH
  - Enhances coagulation and flocculation

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Chemical Treatment

- Sedimentation
  - Water flows to basin and settles
  - Requires 6 hrs detention time
  - Factors influence settling time
  - Sludge is removed periodically
  - Settling tank zones

Sludge Disposal

- Sludge disposal is needed
- Thick sludge blankets cause problems
  - Create taste and odor problems
  - Reduce tank capacity
  - Gas forms, causing solids to float
- Disposal in lagoons, sewers, or dewatered

Filtration

- Final step in removing matter, organisms
  - Removes suspended solids
  - Removes pathogens
- Final step before disinfection
- Rapid sand filter commonly used

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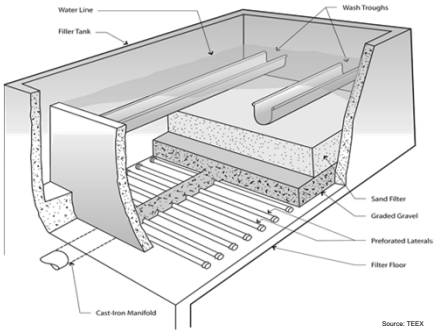
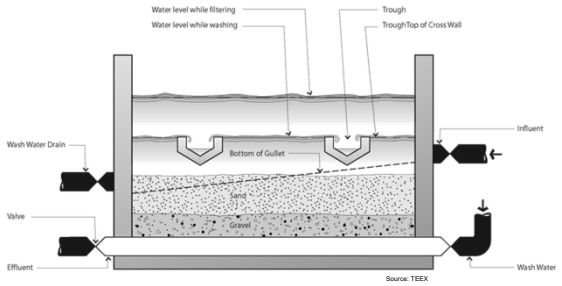
Filtration - Sand Filter



Rapid Sand Filter Cross-Section



Disinfection of Surface Water

- TCEQ disinfection requirements
  - Disinfection prior to storage
  - Pretreatment/storage facilities disinfection
  - Standby disinfection equipment
  - 50% excess capacity of highest dosage
- Chemicals used for disinfection

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Surface Water Treatment Rules

- Turbidity limits
- Disinfection requirements
- Tracer studies
- Surface water influence on well water
- Fluoridation requirements

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Module 5

Review Questions

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End of Module 5

Next Module: Disinfection

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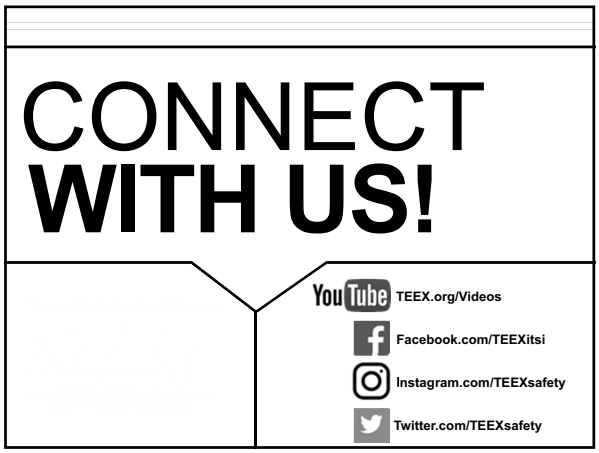

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Module 6

Disinfection

Terminal Objective

Upon the successful completion of this module, the participant will be able to summarize the process for the disinfection of water.

Enabling Objectives

1. Outline the processes related to the microbiological quality of water.
2. Explain the various facets of chlorination.
3. Give examples of alternative disinfectants.

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Instructional Guidance

Time

2 hours 50 minutes

Materials/Equipment

1. Participant manual
2. Laptop with presentation slides for module 6
3. Internet connectivity
4. Video/data projector
5. Screen or monitor

Instructor Preparation

Prepare projector and position first presentation slide.

Application of Participants' Knowledge/Skills

Ask participants to complete the review questions at the end of the module and allow them ample time.

Evaluation of Participants

Go over the review questions at the end of the module, answering any questions the participant may still have.

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Introduction

Slides 1-4

Disinfection destroys disease-causing microorganisms called pathogens. Disinfection kills pathogens without sterilization, which kills all microorganisms. Sterilizing drinking water is not necessary because most microorganisms are not pathogens.

The process of disinfection of water includes statistical sampling, comparison with regulatory requirements, and an acceptable application of chemical disinfection. We will examine chlorine application and personal safety precautions in detail.

Microbiological Quality

Revised Total Coliform Rule

Slides 5-6

The Environmental Protection Agency (EPA) published the Revised Total Coliform Rule (RTCR) in the Federal Register (FR) on February 13, 2013 (78 FR 10269) and minor corrections on February 26, 2014 (79 FR 10665). The RTCR is the revision to the 1989 Total Coliform Rule (TCR) and is intended to improve public health protection.

All public water systems (PWSs) must comply with the RTCR starting April 1, 2016, or an earlier state effective date. Until then, PWSs must continue complying with the 1989 TCR.

Total coliforms are a group of related bacteria that are (with few exceptions) not harmful to humans. A variety of bacteria, parasites, and viruses, known as pathogens, can potentially cause health problems if humans ingest them. EPA considers total coliforms a useful indicator of other pathogens for drinking water. Total coliforms are used to determine the adequacy of water treatment and the integrity of the distribution system.

Key provisions of the RTCR include:

- Setting a maximum contaminant level goal (MCLG) and maximum contaminant level (MCL) for E. coli for protection against potential fecal contamination.
- Setting a total coliform treatment technique (TT) requirement.
- Requirements for monitoring total coliforms and E. coli according to a sample siting plan and schedule specific to the PWS.
- Provisions allowing PWSs to transition to the RTCR using their existing Total Coliform Rule (TCR) monitoring frequency, including PWSs on reduced monitoring under the existing TCR.

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- Requirements for seasonal systems (such as, Non-Community Water Systems not operated on a year-round basis) to monitor and certify the completion of a state-approved start-up procedures.
- Requirements for assessments and corrective action when monitoring results show that PWSs may be vulnerable to contamination.
- Public notification (PN) requirements for violations.
- Specific language for CWSs to include in their Consumer Confidence Reports (CCRs) when they must conduct an assessment or if they incur an E. coli MCL violation.

For more information on the Revised Total Coliform Rule, please see the Quick Reference Guide from EPA on the reference CD.

Waterborne Disease

Most bacteria are necessary for life and help digest food. However, some bacteria, called pathogens, cause diseases. Waterborne or water-carried pathogens live and grow in the intestines of infected people. Pathogens are present only if the person is infected! If fecal matter (intestinal waste) of an infected person enters a water supply, pathogens can be transmitted to a healthy person.

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Diseases transmitted by unsafe water include typhoid, paratyphoid, bacillary dysentery, amoebic dysentery, hepatitis, gastroenteritis, cholera, Legionnaires' disease, polio, giardiasis, cryptosporidiosis, and others. These diseases are intestinal disorders.

Indicator Microorganisms

Slide 8

Pathogens are difficult to detect because there are few of them compared to the number of helpful bacteria and it is not practical to test each water sample for all diseases. Therefore, samples are tested for microorganisms that indicate fecal contamination. The coliform group of bacteria is the indicator microorganism.

The term "total coliform" includes non-fecal and fecal coliform organisms. Non-fecal coliform are typically found in the soil. Fecal coliform live in the intestines of humans and warm-blooded animals. The Escherichia (E.) coli coliform are the most specific indicator of intestinal contamination. Generally, ingesting coliform bacteria does not cause health effects in most people; however, some strains of E.coli can cause severe health effects.

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Slide 9

The presence of fecal coliform or E. coli bacteria in a water sample indicates that intestinal waste is in the sample; therefore, there is a potential risk of waterborne disease. Fecal matter is not dangerous unless the intestine is infected with pathogens. However, because it is not possible to determine if the source of the fecal matter is an infected or healthy person, a positive fecal coliform or E. coli water sample is alarming because it indicates the sample contains fecal waste and possibly pathogens!

Slide 10

The MCL for microbial or bacteriological contaminants applies to public water systems as provided in 30 TAC 290.109 of this title (relating to Microbial Contaminants). The MCL for microbiological contaminants is based on the presence or absence of Escherichia coli (E. coli).

Monitoring Requirements

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The following regulations are excerpts taken from §290.109. For more information, see the complete reference. Regulatory guidance on coliform monitoring (RG-421) is available on the TCEQ website and on the reference CD.

> Monitoring requirements for microbial contaminants. Public water systems shall collect samples for total coliform, fecal coliform, E. coli (or other approved fecal indicator) at sampling sites and a sample collection schedule, as designated by the public water system, which are subject to review and revision as directed by the executive director. All compliance samples must be collected at sampling sites and a sample collection schedule that are representative of water throughout the distribution system and shall be reflected in the public water system's Sample Siting Plan and included with the public water system's monitoring plan in accordance with §290.121 of this title (relating to Monitoring Plans). All public water systems shall develop a written Sample Siting Plan as described in paragraph (6) of this subsection. [30 TAC 290.109(d)]

Sampling Locations

The Texas Administrative Code states:

> Routine microbial sampling locations. Public water systems shall routinely monitor for microbial contaminants at the following locations.
>
> Public water systems must collect routine distribution coliform samples at a customer's premise, dedicated sampling station, or other designated compliance sampling location at active service connections which are representative of water quality

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throughout the distribution system. Other sampling sites may be used if located adjacent to active service connections.

Public water systems shall collect distribution coliform samples at locations specified in the public water system's Sample Siting Plan which shall be included in the public water system's monitoring plan. [30 TAC 290.109(d)(1)(A)–(B)]

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Sampling Frequency

Community and non-community PWSs must collect a minimum number of coliform samples based on the residential population served by the system.

A PWS that uses surface water or groundwater under the direct influence of surface water must sample throughout the month. A PWS that uses only purchased water or groundwater not under the influence of surface water, serving more than 4,900 persons, must sample throughout the month. A PWS that uses only purchased water or groundwater not under the influence of surface water, serving 4,900 persons or less, may take all samples on a single day if taken from different sites. All public water systems shall collect at least the minimum number of required routine microbial samples even if the public water system has had an E. coli MCL violation under any of the conditions as described in subsection (b)(1)(A) - (D) of this section or has exceeded the coliform treatment technique triggers as described in subsection (c)(1) and (2) of this section.
[30 TAC 290.109(d)(2)(B)–(F)]

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A public water system may conduct more microbial compliance monitoring than is required by this subsection to investigate potential problems in the public water system treatment facilities and distribution system and use monitoring to assist in identifying problems. A public water system may collect more than the minimum number of required routine samples required by this subsection. A public water system that collects more than the minimum number of required routine samples required by this subsection shall include the results of these samples in calculating whether the coliform treatment technique triggers as described in subsection (c)(1) and (2) of this section have been exceeded. The additional routine sample sites shall be included in the public water system's Sample Siting Plan and collected in accordance with the Sample Siting Plan and shall be representative of water throughout the distribution system.
[30 TAC 290.109(d)(2)(G)]

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Collecting Bacteriological Samples

Slide 4

Collecting water samples for bacteriological testing is an important operator responsibility. Samples must be representative of the system, collected in sterile containers, and not contaminated during the sampling process. Test results are reported as positive (coliform found), negative (not found), or unsuitable for analysis.

Sampling Steps

1. Determine the number of samples required (Table 6.1).

Table 6.1: Required Number of Coliform Samples and Sampling Events *(Source: TCEQ)*

Required Number of Coliform Samples		
If your system serves this many people...	Then you must collect at least this many coliform samples each month:	And your sampling events must occur at least this frequently:
1 to 1,000	1	Once each month, rotating through five representative sampling sites
1,001 to 2,500 2,501 to 3,300 3,301 to 4,100 4,101 to 4,900	2 3 4 5	Once a month or twice a month at regular intervals rotating through five representative sampling sites
4,901 to 5,800 5,801 to 6,700 6,701 to 7,600 7,601 to 8,500 8,501 to 12,900	6 7 8 9 10	Twice a month at regular intervals
12,901 to 17,200	15	3 times a month at regular intervals
17,201 to 21,500 21,501 to 25,000	20 25	4 times a month at regular intervals

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Table 6.1: Required Number of Coliform Samples and Sampling Events *(Continued) (Source: TCEQ)*

Required Number of Coliform Samples		
25,001 to 33,000	30	
33,001 to 41,000	40	
41,001 to 50,000	50	
50,001 to 59,000	60	
59,001 to 70,000	70	
70,001 to 83,000	80	
83,001 to 96,000	90	
96,001 to 130,000	100	
130,001 to 220,000	120	Daily If you have questions about the TCEQ interpretation of "daily sampling" call the Drinking Water Quality Team at 512/239-4691.
220,001 to 320,000	150	
320,001 to 450,000	180	
450,001 to 600,000	210	
600,001 to 780,000	240	
780,001 to 970,000	270	
970,001 to 1,230,000	300	
1,230,001 to 1,520,000	330	
1,520,001 to 1,850,000	360	
1,850,001 to 2,270,000	390	
2,270,001 to 3,020,000	420	
3,020,001 to 3,960,000	450	
3,960,001 or more	480	

2. Develop a written sample siting plan.

   The required plan assures samples are taken from active, representative services. TCEQ inspectors will review this plan.

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   A. Community water systems

      1. Select representative sites. Consider main sizes, looped areas, dead-end mains. Systems taking five samples/month or less, select at least five sites.
      2. Give sites descriptive address. Inspectors locate sites.
      3. Make sites easily noted and explainable.
      4. Sites must include the following:
         a) Designation number or letter
         b) Address/location
         c) Main size at sampling point
         d) Pressure plane or pump station designation

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   B. Non-community water systems

      1. Use maximum daily population for number of samples.

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a) Convenience stores and restaurants: Select one point representing plumbing.

b) RV parks, campgrounds, etc.: Develop plans as a community system.

2. Locate sites on distribution map.
3. List sites as you would community systems (Table 6.2).

Slide 17

4. Sample Siting Plan Requirements according to 30 TAC 290.109(d)(6):

   All public water systems shall develop and complete a written Sample Siting Plan as described in this paragraph that identifies routine and repeat microbial sampling sites and a sample collection schedule as required by this subsection that are representative of water throughout the distribution system. The Sample Siting Plan shall include all groundwater sources and any associated sampling points necessary to meet the requirements of this subsection. The Sample Siting Plan shall be included as a part of the public water system's monitoring plan as described in §290.121 of this title. Sample Siting Plans shall be completed in a format specified by the executive director and are subject to review and revision by the executive director.

   All public water systems shall collect routine and repeat samples according to a written Sample Siting Plan. All routine and repeat sample site locations and any sampling point locations necessary to meet the requirements of this subsection shall be reflected in the written Sample Siting Plan.

   All public water systems shall include any required SOP for any proposed repeat sampling sites as described in paragraph (3)(C) of this subsection in the Sample Siting Plan. As required by the executive director, the executive director may review, revise, and approve any repeat sampling proposed by public water systems under paragraph (3)(C) of this subsection.

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   The Sample Siting Plan shall include a distribution system map which identifies distribution system valves and mains as described

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in §290.46(n)(2) of this title. The distribution system map shall also include the location of all routine microbial sample sites, water main sizes, entry point source locations, water storage facilities, and any pressure plane boundaries.

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All public water systems shall update their written Sample Siting Plan and map as necessary, or as requested by the executive director, to identify the most current microbial routine and repeat sampling sites and a sample collection schedule that are representative of water throughout the public water system's distribution system.

All public water systems shall maintain a copy of their updated Sample Siting Plan and map on-site at the public water system for inspection purposes and at the request of the executive director, provide a copy of their Sample Siting Plan and/or map to the executive director for review and/or revision purposes.

Table 6.2: Coliform Sample Siting Plan

Site Number or Letter	Street Address or Exact Location	Main Size	Pressure Plane/ Pump Station

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3. Obtain sample containers.

   Collect samples in sterile containers containing sodium thiosulfate, which neutralizes the chlorine residual. Obtain prepared containers from state offices or laboratories in major cities.

Learning Check

1. Why does the container need sodium thiosulfate in it?

   a. To dechlorinate the sample

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4. Obtain routine samples from designated sites.

   Take samples at representative points within the distribution system. The point must be sanitary—no overhanging plants, insect nests, or leaky faucets. A common sampling point is an outside house faucet.

5. Flush the service line.

   Open the faucet fully, flushing the line. The water temperature changes when it comes from the main.

6. Test the chlorine residual.

7. Flame or disinfect the faucet.

   Close the faucet and flame it with a propane torch or alcohol burner, or disinfect with alcohol, hydrogen peroxide, or bleach, allowing extra contact time for the bleach to disinfect the faucet prior to sample collection.

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8. Fill the sample container.

   Open the faucet to a pencil-sized stream and fill the container with at least 100 mL, but not completely full. Do not touch the inside of the container or cap. Do not use a container older than six months.

9. Fill out the form (Figure 6.1).

   The container form must be completely filled out. Mark the monthly sample "distribution."

10. Send the sample and form to the laboratory.

    Get samples to a lab within 30 hours or they are rejected. Cool the samples in ice prior to and during transport. Keep samples off dashboards! Heat stimulates biological growth!

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For Laboratory Use Only	Sample Number	Date and Time Received

TEXAS Department of State Health Services
Specimen Acquisition: (512) 458-7598

G-19 Water Bacteriology Form Rev (02/11)
http://www.dshs.state.tx.us/lab

Place DSHS Bar Code Label Here

Please indicate the laboratory where the sample was submitted by checking the appropriate box below:

☐ **Austin Laboratory**
Laboratory Services Section, MC-1947
P. O. Box 149347, Austin, Texas 78714-9347
Courier: 1100 W. 49th Street, Austin, Texas 78756
(888) 963-7111 x7318 or (512) 458-7318
NELAC Certificate No. T104704297

☐ **South Texas Laboratory**
1301 S. Rangerville Road
Harlingen, TX 78552
(956) 364-8746
(956) 412-8794 Fax
NELAC Certificate No. T104704315

Sample Collection Data

Date and Time Collected: (** REQUIRED)	**Sample Site:** (Address or other description – do not use sample site number)
Date: MM DD YY (mm/dd/yy)	
Time: HH MM ☐ AM ☐ PM	

County:	**Sampler's Name:**	**Phone Number: (with area code)**

SYSTEM TYPE (Check one)	**SAMPLE TYPE** (Public Water Systems Only) (Check one)	**WATER SOURCE** (Check water source and provide well depth, if appropriate.)
☐ Public (PWS) ☐ Private (Individual) Other: ☐ School ☐ Bottled ☐ Dairy ☐ _____	☐ Routine/Distribution ☐ Raw : Well ID _____ ☐ Construction ☐ Special _____ ☐ Repeat ☐ Replacement ☐ Other: _____	☐ Ground Water *(Well)* Well Depth: _____ ☐ Surface Water *(Lake, River)*

DISINFECTANT RESIDUAL
MANDATORY FOR ALL SAMPLES COLLECTED FOR TCEQ. SAMPLE SHOULD NOT BE COLLECTED IF RESIDUAL IS NOT PRESENT.
Disinfectant Residual _____ mg/L ☐ Free Chlorine ☐ Chloramine (Total Chlorine)

Sample Submitter

Public Water System ID: (** REQUIRED for PWS. 7-digits)	**Public Water System (PWS) Name:**

Send Sample Results To: (** REQUIRED)

Name:	
Address:	
City, State, Zip:	
Phone: (area code)	( )

☐ Owner ☐ Operator ☐ Other

Results to be:
☐ Mailed ☐ Picked Up ☐ Faxed to : ( )

THE SUBMITTER WILL BE BILLED FOR ALL TESTING. There is a fee for this analysis.

DSHS is not responsible for 3rd party payment arrangements.

If you have questions about this fee, please call (512) 458-7111 ext. 6030.

COPIES: LABORATORY (white copy) CUSTOMER (yellow copy)

SAMPLE

Figure 6.1: Sample form. *Source: Department of State Health Services.*

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What to Do When a Sample Is Positive

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If a routine sample is positive, the PWS must collect repeat samples within 24 hours of notification or as soon as possible if the lab is closed.

The executive director may extend the 24-hour limit on a case-by-case basis if the public water system has a logistical problem in collecting the repeat samples within 24 hours that is beyond the public water system's control. All public water systems shall collect no fewer than three repeat samples for each total coliform-positive sample found.

The public water system must collect all repeat samples on the same day, except a public water system with a single service connection may collect daily repeat samples over a three-day period until the required number of repeat samples has been collected.

One repeat sample must be taken at the original positive sample site and at least one repeat sample within five connections upstream and downstream of the original site.

If the positive sample was collected at the end of the distribution system or one service connection away from the end of the distribution system, one repeat sample is taken at that point and all other repeat samples are taken within five connections upstream.

Positive Repeat Samples

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If any repeat samples are positive, another set of repeat samples must be collected. The additional samples must be collected within 24 hours of the public water system being notified of the positive result or as soon as possible if the local laboratory is closed. The executive director may extend the 24-hour limit on a case-by-case basis if the public water system has a logistical problem in collecting the repeat samples within 24 hours that is beyond the public water system's control.

The public water system must repeat this process until one of the following occurs:

- Total coliforms are not detected in one complete set of repeat samples; or
- A coliform treatment technique trigger as described in subsection (c)(1) and (2) of this section has been exceeded.

If a treatment technique trigger as described in subsection (c)(1) and (2) of this section is exceeded as a result of a routine sample being total coliform-positive, public water systems are required to conduct only one round of repeat monitoring for each total coliform-positive routine sample.

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Invalidation of Positive Samples

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Results of all routine and repeat samples not invalidated are used to determine compliance with the coliform MCL. Samples taken after pipe placement, replacement, or repair, are not used to determine compliance.

The executive director may invalidate a coliform-positive sample if one of the following conditions is met:

- The results of repeat samples collected, as required by this section, determine that the total coliform-positive sample resulted from a domestic or other non-distribution system plumbing problem. The executive director cannot invalidate a sample on the basis of repeat sample results unless all repeat sample(s) collected at the same tap as the original total coliform-positive sample are also total coliform-positive, and all repeat samples collected within five service connections of the original tap are total coliform-negative. Under those circumstances, the system may [cease resampling and] request that the executive director invalidate the sample. The system must provide copies of the routine positive and all repeat samples.
- If there are substantial grounds to believe that the total coliform-positive result is due to a circumstance or condition which does not reflect water quality in the distribution system. In this case, the system must still collect all repeat samples required by this section, and use them to determine compliance with the E. coli MCL as described in subsection (g) of this section and whether a coliform treatment technique trigger has been exceeded as described in subsection (c) of this section. The system must provide written documentation which must state the specific cause of the total coliform written documentation which must state the specific cause of the total coliform-positive sample, and the action the system has taken, or will take, to correct this problem. The executive director may not invalidate a total coliform-positive sample solely on the grounds that all repeat samples are total coliform-negative.
- If the laboratory provides written notice that improper sample analysis caused the total coliform-positive result or that the sample was unsuitable for analysis.

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If a sample is invalidated by the laboratory, the public water system must collect another sample from the same location as the original sample within 24 hours of being notified, or as soon as possible if the laboratory is closed, and have it analyzed for the presence of total coliform. The system must continue to resample within 24 hours and have the samples analyzed until it obtains a valid result.

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Evaluating the Results

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A public water system is in compliance with the MCL for *Escherichia coli* (*E.coli*) unless the public water system does any of the following:

- Fails to submit the required number of routine or repeat samples
- Fails to report positive sample results or post a required public notice
- Has an *E.coli*-positive repeat sample following a total-coliform-positive routine sample
- Has a total coliform-positive repeat sample following an *E.coli*-positive routine sample
- Fails to take all required repeat samples following an *E.coli*-positive routine sample
- Fails to test for *E.coli* when any repeat sample tests positive for total coliform

Treatment Technique Triggers and Assessment Requirements for Microbial Contaminants

The following section is taken from TCEQ Subchapter F:

> All public water systems shall comply with the requirements as described in this subsection. Public water systems shall conduct assessments after exceeding any of the treatment technique triggers as described in paragraphs (1) and (2) of this subsection.

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Level 1 treatment technique triggers are:

- For a public water system that collects 40 or more distribution samples per month, the treatment technique trigger is defined as when more than 5.0% of samples collected in a month are total coliform-positive.
- For a public water system that collects fewer than 40 distribution samples per month, the treatment technique trigger is defined as when two or more samples collected in a month are total coliform-positive.
- When a public water system fails to collect all required repeat samples after a total coliform-positive result.

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Level 2 treatment technique triggers are:

An *E.coli* MCL violation as specified in subsection (b)(1)(A) - (D) of this section occurs.

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A second Level 1 treatment technique trigger occurs as defined in paragraph (c)(1) of this section, within a rolling 12-month period. If the executive director has determined the reason that the samples that caused the first Level 1 treatment technique trigger were total coliform-positive and has established that the public water system has corrected the problem, a public water system will not be required to conduct and complete a Level 2 assessment. The public water system shall have identified any sanitary defect and provided adequate documentation to the executive director in the initial Level 1 assessment which established the reason that caused the first Level 1 treatment technique trigger and that the public water system corrected the problem. If the executive director has determined that a public water system is not required to conduct a Level 2 assessment based on the occurrence of a second Level 1 treatment technique trigger within a rolling 12-month period, the public water system shall still conduct the required Level 1 assessment.

Treatment technique assessment requirements are:

Level 1 and Level 2 assessments are conducted in order to identify the possible presence of sanitary defects and defects in distribution system coliform monitoring practices. The assessments may also indicate that no sanitary defects were identified. When conducting assessments, systems shall ensure that the assessor evaluates minimum elements that include review and identification of inadequacies in sample sites; sampling protocol; sample processing; atypical events that could affect distributed water quality or indicate that distributed water quality was impaired; changes in distribution system maintenance and operation that could affect distributed water quality (including, but not limited to water storage); source and treatment considerations that bear on distributed water quality; and existing water quality monitoring data. The system shall conduct and complete the assessment in the format as prescribed by the executive director that tailors specific assessment elements with respect to the size and type of the system and the size, type, and characteristics of the distribution system.

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Level 1 and Level 2 assessments shall be conducted and completed by the public water system, licensed operators as required under §290.46(e) of this title (relating to Minimum Acceptable Operating Practices for Public Drinking Water Systems), or other parties approved by the executive director. The public water system, licensed operators, as required under

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§290.46(e) of this title, and other parties approved by the executive director shall have also completed any training required by the executive director in writing, upon notice to the public water system, licensed operators, and other parties approved by the executive director.

Other parties approved by the executive director include, but are not limited to:

- backflow prevention assembly testers and customer service inspectors licensed under Chapter 30 of this title (relating to Occupational Licenses and Registrations);
- plumbing inspectors and water supply protection specialists licensed by the Texas State Board of Plumbing Examiners;
- licensed professional engineers licensed by the Texas Board of Professional Engineers;
- circuit riders or technical assistance providers under contract with the executive director or other government agency as approved by the executive director; or
- utility supervisor or manager supported by various utility staff or other individuals that meet the assessment requirements as described in this paragraph.

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The Level 1 and Level 2 assessments shall be conducted and completed consistent with all directives set forth by the executive director and with respect to the size, type, and characteristics of the public water system. When conducting assessments, at a minimum, public water systems shall ensure that the following items are evaluated:

- Review and identification of inadequacies in sample sites
- Sampling protocol
- Sample processing
- Atypical events that could affect distributed water quality or indicate that distributed water quality was impaired
- Changes in distribution system maintenance and operation that could affect distributed water quality (including, but not limited to water storage)
- Source and treatment considerations that bear on distributed water quality, where appropriate
- Existing water quality monitoring data

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A public water system shall conduct a Level 1 assessment when the public water system exceeds one of the treatment technique triggers in paragraph (1) of this subsection.

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A Level 1 assessment shall be completed and submitted to the executive director as soon as practical, but in no case later than 30 days after the public water system learns that it has exceeded a trigger.

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If the executive director determines that the Level 1 assessment is not sufficient, the public water system shall consult with the executive director and submit a revised assessment form to the executive director within 30 days from the date of consultation.

The executive director will determine if the public water system has identified a cause of the trigger and, if so, was the cause corrected, or has an acceptable schedule to correct the problem been included.

A public water system shall ensure that a Level 2 assessment is conducted consistently with all directives set forth by the executive director if the public water system exceeds one of the treatment technique triggers in paragraph (2) of this subsection. The public water system shall comply with any expedited actions or additional actions required by the executive director in the case of an E. coli MCL violation.

The public water system shall ensure that a Level 2 assessment is completed by the public water system, licensed operators as required under §290.46(e) of this title, or by parties approved by the executive director as soon as practical after any trigger in paragraph (2) of this subsection. The public water system shall submit a completed executive director-approved Level 2 assessment form to the executive director within 30 days after the public water system learns that it has exceeded a trigger.

If the executive director determines that the completed Level 2 assessment is not sufficient or the proposed timetable for any corrective actions not completed is not sufficient, the public water system shall consult with the executive director. If any revisions are required after consultation, the public water system shall submit a revised assessment form to the executive director within 30 days.

After the Level 2 assessment is submitted, the executive director will determine if the public water system has identified the cause of the trigger and corrected the cause, or has included an acceptable timetable for correcting the cause.

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Public water systems must correct sanitary defects found through either Level 1 or Level 2 assessments described in this subsection. For corrective actions not completed by the time of submission of the assessment form, the public water system must complete the corrective actions in compliance with a timetable approved by the executive director in consultation with the public water system. The public water system must notify the executive director when scheduled corrective actions have been completed.

At any time during the assessment or corrective action phase, either the public water system or the executive director may request a consultation with the other party to determine the appropriate actions. The public water system shall consult with the executive director on all relevant information that may impact its ability to comply with a requirement of this subsection.

Public Notification

Slide 33

Procedure for public notification is decided by the TCEQ. *Always consult the TCEQ before notifying the public of a violation!*

Acute Violation: Notify the public within 24 hours by radio and television using the words "Serious Health Concern."

Non-Acute Violation: A repeat positive total coliform sample following a positive total coliform routine sample is a non-acute risk to public health. Notify the public within 14 days by mail or newspaper using the words "Possible Health Concern."

TCEQ Special Precautions

Slide 34

According to 30 TAC 290.46:

> Special precautions, protective measures, and boil water notices shall be instituted by the public water system in the event of low distribution pressures (below 20 pounds per square inch (psi)), water outages, microbiological samples found to contain Escherichia coli (E. coli) (or other approved fecal indicator) [coliform organisms], failure to maintain adequate disinfectant residuals, elevated finished water turbidity levels, or other conditions which indicate that the potability of the drinking water supply has been compromised. Special precautions, protective measures, and boil water notices are corrective or protective actions which shall be instituted by the public water system to comply with the requirements of this subsection.

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Use the pressure loss response flowchart to determine the necessary action (Figure 6.2).

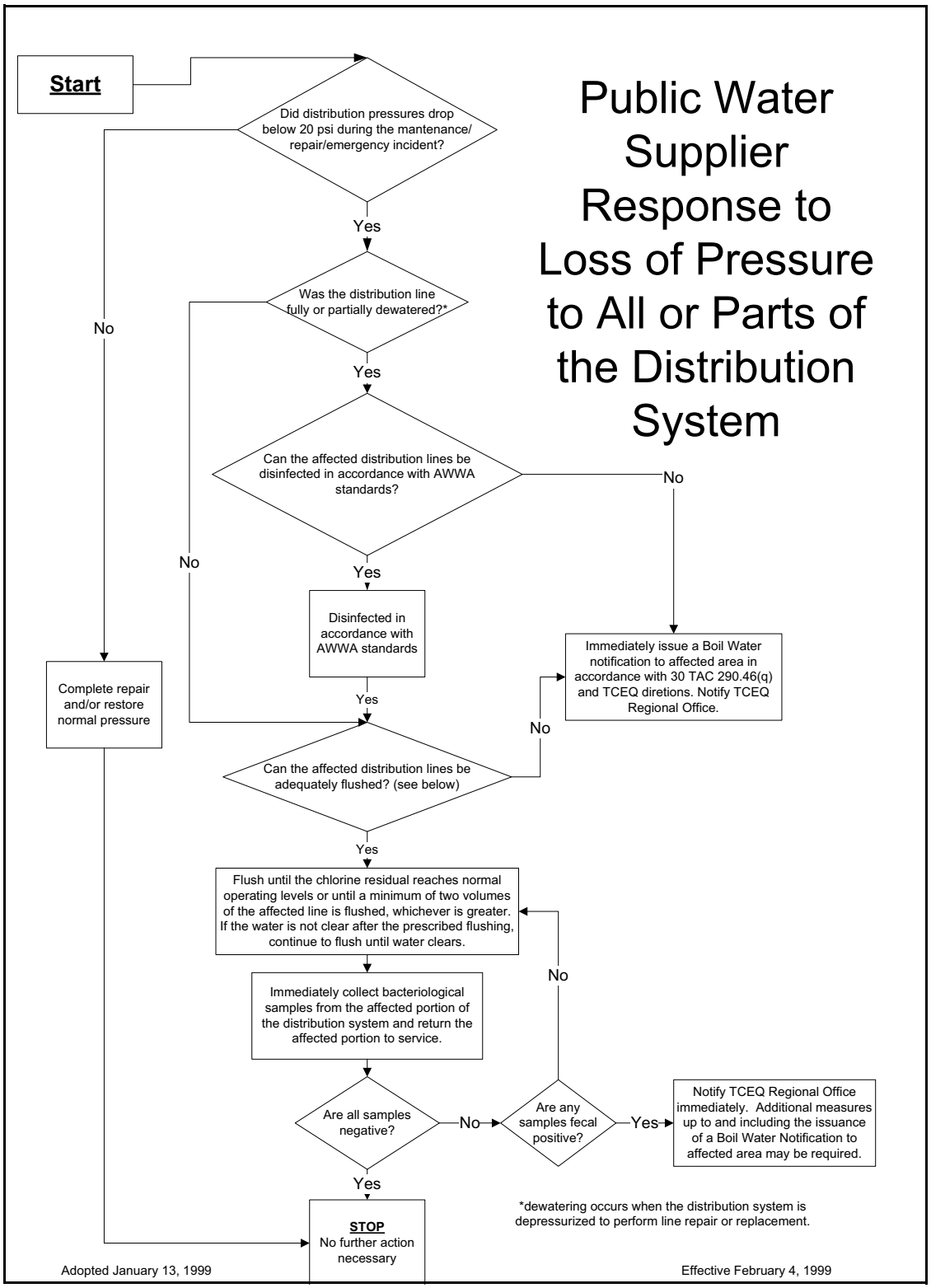
Public Water Supplier Response to Loss of Pressure to All or Parts of the Distribution System
Start
Did distribution pressures drop below 20 psi during the mantenance/ repair/emergency incident?
Yes
No
Was the distribution line fully or partially dewatered?*
Yes
No
Can the affected distribution lines be disinfected in accordance with AWWA standards?
No
Yes
Disinfected in accordance with AWWA standards
Immediately issue a Boil Water notification to affected area in accordance with 30 TAC 290.46(q) and TCEQ diretions. Notify TCEQ Regional Office.
Complete repair and/or restore normal pressure
Yes
No
Can the affected distribution lines be adequately flushed? (see below)
Yes
Flush until the chlorine residual reaches normal operating levels or until a minimum of two volumes of the affected line is flushed, whichever is greater. If the water is not clear after the prescribed flushing, continue to flush until water clears.
No
Immediately collect bacteriological samples from the affected portion of the distribution system and return the affected portion to service.
Are all samples negative?
No
Are any samples fecal positive?
Yes
Notify TCEQ Regional Office immediately. Additional measures up to and including the issuance of a Boil Water Notification to affected area may be required.
Yes
STOP
No further action necessary
*dewatering occurs when the distribution system is depressurized to perform line repair or replacement.
Adopted January 13, 1999
Effective February 4, 1999

Figure 6.2: Pressure loss response flowchart. *Source: TEEX.*

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If the chart indicates that a "boil water notification" is required, make the notification within 24 hours using the TCEQ format found in TAC 30 Chapter 290 rules (Figure 6.3).

Boil Water Notification

(Insert Name of Water System)

Due to conditions that have occurred recently in the water system, the Texas Commission on Environmental Quality has required the system to notify all customers to boil their water prior to consumption.

To ensure destruction of all harmful bacteria and other microbes, water for drinking, cooking and ice making should be boiled and cooled prior to use for drinking water or human consumption purposes. The water should be brought to a vigorous boil and then boiled for two minutes. In lieu of boiling, individuals may purchase bottled water or obtain water from some other suitable source. When it is no longer necessary to boil water, the public water system officials will notify customers [you] that the water is safe for drinking water or human consumption purposes.

If you have any questions regarding this matter, you may contact

(a) _____ at (b) _____
Utility Official(s) *Phone Number(s)*

INSTRUCTIONS:

List more than one utility official and phone number. Do not list the TCEQ as the primary contact. If a customer wishes to call the TCEQ, have them call 512/239-4691.

Figure 6.3: TCEQ Boil Water Notification. *Source: TEEX.*

A copy of the notice shall be provided to the executive director within 24 hours or no later than the next business day after issuance by the public water system and shall be accompanied with a signed Certificate of Delivery.

Boil water notices shall remain in effect until water distribution pressure in excess of 20 psi can consistently be maintained, a minimum of 0.2 mg/L free chlorine residual or 0.5 chloramine residual (measured as total chlorine) is present throughout the system, and water samples collected for microbiological analysis are found negative for coliform organisms. Once these conditions are met, the customers must be notified in a manner similar to the original notice.

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Chlorination

Disinfection Purposes

Slide 35

In the United States, disinfection is usually accomplished with some form of chlorine. In Texas, all public water systems are required to have chlorination facilities. Chlorination is the most important process in the production of potable water.

All water in storage or transported through the distribution system must have a disinfectant residual. A disinfectant residual is the amount of chlorine left over after the demand has been satisfied. This will be discussed later in this module. To be effective, the disinfectant must be present in drinking water at all times.

In addition to disinfection of the water supply, chlorine is used for the following:

- Taste and odor control
- Oxidation of iron and manganese
- Oxidation of hydrogen sulfide
- Disinfection of repairs

Effectiveness of Disinfection

Slide 36

The principal factors that influence disinfection are:

- concentration of the disinfectant,
- contact time of the disinfectant with the water being treated,
- temperature of the water, and
- pH of the water.

Other factors can also affect disinfection such as turbidity, amount and type of demand, and the type of residual being utilized.

Chlorine Sources

Slide 37

Hypochlorites

Sodium hypochlorite is liquid bleach sold under various trade names. It is produced by reacting chlorine with sodium hydroxide and water. It comes in solutions of 5.25% to 15% sodium hypochlorite, the percentage of available chlorine. A gallon of bleach containing 5.25% sodium hypochlorite (5.25% available chlorine) contains about 0.44 lbs. of chlorine.

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Bleach is not liquid chlorine. Liquid chlorine is pure, liquefied gas chlorine.

Small water systems use bleach because only a chemical pump and mixing tank are needed, and there is no risk of gas leaks. Higher cost is a disadvantage to bleach.

If used in public drinking water, bleach must be National Sanitation Foundation (NSF) approved.

Calcium hypochlorite comes in granular and powder form under various trade names. Calcium hypochlorite is made by reacting chlorine with lime. Compounds usually contain about 65% available chlorine. A 100-lb. container of calcium hypochlorite (65%) contains 65 lbs. of chlorine and 35 lbs. of lime.

Calcium hypochlorite is not dry chlorine. Dry chlorine is pure chlorine, liquid or gas, containing less than 150 ppm water.

Some small water systems use calcium hypochlorite instead of bleach because it is much stronger and sometimes costs less. The feed equipment is identical to bleach solution feeders, except solutions of calcium hypochlorite must be prepared in a mixing tank, allowed to settle, and the clear supernatant (liquid) transferred to a feed tank. If used in public drinking water, calcium hypochlorite must be NSF approved.

Calcium hypochlorite is a powerful oxidizer and will cause an explosion or fire if it contacts oil or other organic material, or gets too hot. It must be stored in a cool place.

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Pure Chlorine

Chlorine is produced by the electrolysis of brine. Common table salt, sodium chloride, NaCl, is used. Sodium hydroxide (caustic) and hydrogen gas are byproducts.

At room temperature, chlorine is a greenish-yellow gas, has a pungent odor, and is 2 1/2 times heavier than air. It is corrosive when wet and is a strong oxidizer, but it does not burn. When cooled and compressed, chlorine gas becomes a liquid that is reddish-yellow (amber) in color. The chemical symbol for chlorine is Cl_2. *Chlorine gas is toxic***.**

Commonly, chlorine is shipped in 150-lb. cylinders, ton containers, and 90-ton railroad cars.

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The maximum sustained gas withdrawal rate from 150-lb. cylinders (vacuum transmission) is 1 lb./day per degree F. The equivalent rate for ton containers (vacuum transmission) is 8 lbs./day per degree F.

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Pressure transmission rates are 42 lbs./day for 150-lb. cylinders and 336 lbs./day for ton containers, based on an air temperature of 70° F.

Chlorination Techniques

Slide 40

Required Capacity

Disinfection capacity for drinking water must be 50% greater than the highest expected dosage.

Hypochlorination

Hypochlorinators use a mixing tank (or mixing tank and feed tank), water, sodium hypochlorite, or calcium hypochlorite fed by a chemical pump. The pump may be manually controlled or meter paced. The solution strength or the pump rate adjusts the amount of chemical applied. Small water systems often use this method.

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Gas Chlorination

Gas chlorinators are used in larger plants. Chlorine enters the unit through the inlet valve under vacuum produced by the injector, powered by water. Then, the gas is metered through a rotameter in lbs,/day or grams/hr. The gas passes through a flow controller and is suctioned into the injector. The chlorine mixes with the water and is carried to the point of use (Figure 6.4).

For additional information on chlorine procedures, see appendix B.

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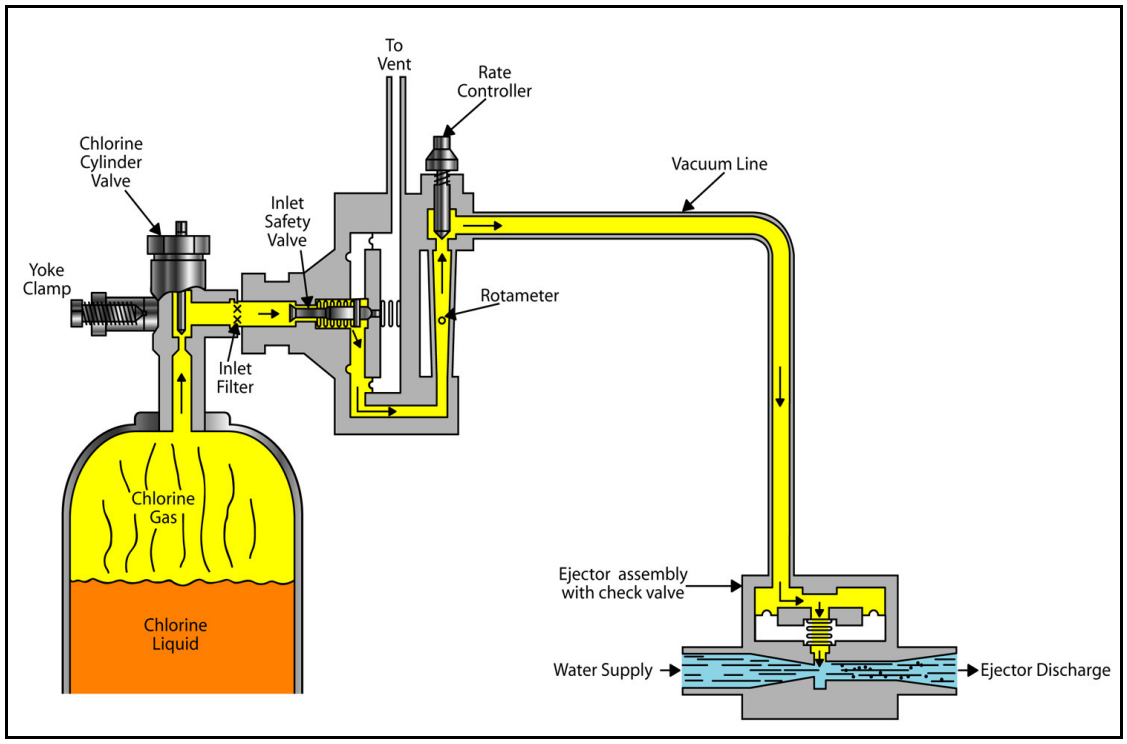

Figure 6.4: Gas chlorinator. *Source: TEEX.*

Dosage, Demand, and Residual

Slide 43

Dosage is the amount of chemical applied in mg/L or ppm. Demand is the amount of chemical used up by reducing agents. Residual is the amount of chemical remaining after reacting with demand.

DOSAGE = DEMAND + RESIDUAL

Slide 44

Disinfectant dosage is the amount of disinfectant added usually expressed as milligrams per liter (mg/L). Demand is the constituents present in the water that will consume the disinfectant. Demand, which is also referred to as reducing agents, can be inorganics, such as iron, manganese, and hydrogen sulfide, or organics, such as bacteria, viruses, etc. After demand is satisfied, a residual is left over. Residual is usually expressed in mg/L. Chapter 290.46(d) (2) of the TCEQ Rules and Regulations requires a free chlorine residual of 0.2 mg/L or a chloramine residual of 0.5 mg/L throughout the distribution system. Together, free chlorine residual and combined residual equal total residual.

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Minimum Residuals Requirements

The following are minimum disinfection residuals in the distribution system:

- Free chlorine residual - 0.2 mg/L
- Chloramine (measured as total residual) - 0.5 mg/L

Ninety-five percent of all distribution residual readings must be above the minimum for every consecutive two-month period. Chlorine residuals are lowest at distribution points farthest from chlorination points.

Maximum Residual Requirements

All community and non-transient, non-community water systems must not exceed a maximum free chlorine or chloramine residual of 4 mg/L based on the running annual average of all distribution samples.

Limiting residuals reduces disinfection byproducts such as trihalomethanes and haloacetic acids. These byproducts, consumed over a long time period, may cause cancer.

The maximum contaminant level (MCL) for THMs is 0.080 mg/L, and the MCL for HAA5 is 0.060 mg/L.

Testing for Chlorine Residual

DPD (N,N-diethyl-p-phenylene-diamine) measures the chlorine residual in water in mg/L. The DPD and chlorine reaction turns the water a pink to red color. The DPD and chlorine reaction can be measured with a pocket colorimeter, benchtop spectrophotometer, manual titration, or automated amperometric titration. A review of the various methods is included in Appendix D.

Chlorine Reactions in Water

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When chlorine gas (Cl2) is added to water, two acids are formed: hypochlorous (HOCl) and hydrochloric acid (HCl). The disinfectant is HOCl, and since it is an acid, pH affects the degree of disinfection. When using a free chlorine residual, a chlorine odor and or taste can occur. When chlorine demand has been satisfied, the chlorine will combine with organic compounds or ammonia in the water to form chlororganics and chloramines, which can also cause taste and odor. The addition of more chlorine will push the residual beyond breakpoint until only a free available residual remains. The taste and odor should dissipate.

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Inorganic and organic matter react with chlorine, reducing or destroying its disinfecting power. These substances are called reducing agents, or demand. Ammonia, iron, manganese, hydrogen sulfide, bacteria, and organic compounds are some chlorine-reducing agents.

Chlorine Demand Curve (Breakpoint Chlorination)

Slide 48

(1) Chlorine satisfies inorganic demand, forming no residual.

(2-3) Chlorine reacts with organics and ammonia. Chlorine and ammonia produce chloramines, disinfectants weaker than free chlorine, but less reactive and longer lasting. They can cause taste and odor. Chloramine residual increases, then decreases as chlorine concentration increases in the chloramines.

(4) After all reactions, any chlorine added will be free residual (Figure 6.5).

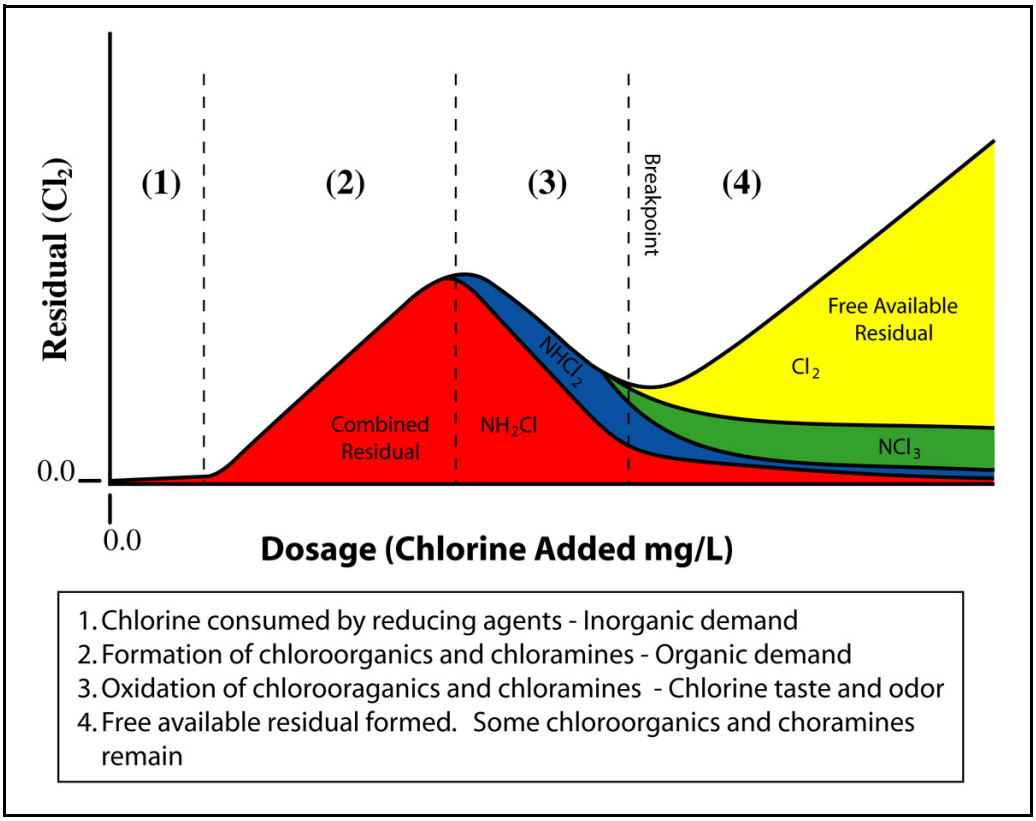

Figure 6.5: Chlorine demand curve. *Source: TEEX.*

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Formation of Chloramine

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Chlorine reacts with ammonia to form chloramine. Unfortunately for the operator, there are three chloramine compounds that can be formed. Monochloramine (NH2Cl) is the desired disinfectant and is formed with Cl:N feed rates of 5:1 or less. This occurs in quadrant 2 of the chart (Figure 6.5). In quadrant 3 of the chart, chlorine is overfed and Dichloramine (NHCl2) forms. When this occurs at Cl:N feed rates of 5:1 to 7:1, disinfection is compromised, and the finished water will have a nasty chlorine taste. An even higher Cl:N feed rate of 7:1 to 8:1 will form Trichloramine (NHCl3), which adds a foul odor to the finished water.

Operators, in an effort to feed only monochloramine, will sometimes feed a small amount of free ammonia, which chemically is correct. If a trace of free ammonia is present, only monochloramine can form. However, free ammonia provides nutrition to the biofilm in the distribution system, which can further degrade the disinfectant residual.

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Bacteria that exist in the biofilm will use free ammonia as food, a process known as nitrification. Nitrification converts the ammonia into nitrite and nitrate. This problem becomes more severe when temperatures are warm and usage low.

Nitrification is minimized by using the following procedures:

- Optimize the chloramination process. Closely monitor free and total chlorine, monochloramine and free ammonia at the treatment plant and in the distribution system.
- Reduce water age in the system by flushing and cycling all water storage tanks.
- Conduct routine system maintenance by high-flow flushing (unidirectional flushing) or pigging.
- Replace aging pipes.

Chlorine Safety

Chlorine is extremely toxic and highly irritating to the nose and throat, causing severe coughing and tissue damage. *Heavy exposure can be fatal!*

A Self-Contained Breathing Apparatus (SCBA) must be readily available, but stored away from the chlorinator room and inspected regularly.

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Chlorinator Rooms and Equipment

Disinfection equipment must have a capacity of at least 50% greater than the highest expected dosage at any time.

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Housing must be aboveground, and chlorinator equipment and chlorine containers must be in separate buildings or separate rooms from mechanical or electrical equipment.

Because chlorine gas is heavier than air, it flows toward the floor. Chlorinator rooms must have high-level and floor-level screened vents. Rooms containing more than one open 150-lb. cylinder must have forced air ventilation, including vents and a fan. The fan switch must be outside the room (Figure 6.6 and Figure 6.7).

Figure 6.6: Chlorine one-ton containers. *Source: TEEX.*

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Figure 6.7: 150-lb. cylinders.
Source: TEEX.

Store chlorine containers between 50° F and 140° F. Heat-sensitive pressure relief plugs in containers melt at about 160° F.

Scales must be provided to determine the amount of disinfectant used and the amount remaining daily.

Hypochlorination solution containers and pumps must be housed and locked to protect against adverse weather and vandalism. The solution container must be covered to prevent contamination.

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Chemical Risk Management

EPA requires any private, municipal, or industrial entity storing or using 2,500 lbs. or more of chlorine to have a chemical risk management program. The TCEQ requires that evacuation procedures be established where one-ton or more chlorine or ammonia container is within 1/4 mile of a residential or other high-density development.

Slide 54

Chlorine Leaks

Detect chlorine leaks by holding an open bottle of 10% ammonium hydroxide (ammonia and water) under the suspected point. If chlorine is escaping, ammonium chloride will appear as a white smoke. The Chlorine Institute does not recommend household ammonia. Repair leaks as soon as possible!

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Slide 55

Before entering a room that contains chlorine gas, the following are suggested:

- Be trained and prepared.
- Wear a fresh air supply.
- Have standby help.
- Have repair equipment.
- Wear a safety harness and lifeline.

In case of leaks, the best source of help is the supplier!

Tightening the packing gland or closing the cylinder valve stops leaks around the container valve stem. If necessary, apply the Chlorine Institute repair kit "A" for 150-pound cylinders or kit "B" for ton containers, then call the supplier!

- If a leak is extensive, potentially exposed persons should move upwind or to the crosswind.
- If a leak develops while transporting containers, keep the vehicle moving until open country is reached.
- A leaking container must not be immersed in a body of water; the leak will get worse and the container may float, allowing gas to leak at the surface.

The operator is at the greatest risk when changing out cylinders or containers. Before breaking connections loose, make sure the chlorine valve is closed and the gas is bled out of the system. Break connections loose slowly. Once the cylinder or container is changed out and connections are tightened, briefly pressurize the system and turn the gas off. Detect any leaks by holding an open bottle of 10% ammonium hydroxide under each connection. If there is a leak, a white smoke will form as the ammonia combines with the leaking chlorine gas. Repair the leak and then retest using the ammonia bottle. When no leaks are detected, open the chlorine valve one-quarter turn and place the system into service. The valve wrench should remain on the open valve.

First Aid

Chlorine irritates the eyes, nose, and throat. High concentrations cause vomiting and labored breathing that can progress to suffocation.

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There should be first aid equipment and trained personnel to aid anyone contacting chlorine gas:

- Take patient to fresh, warm air. Allow them to sit or lie down with head and trunk elevated.

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- Call medical help.
- Wash skin or clothing in a safety shower or with a garden hose.
- Flush eyes with cool water at least 15 minutes.
- If the victim is not choking, give coffee, tea, milk, or peppermint candy to relieve throat irritation, but do not give alcohol.
- If necessary, give artificial respiration or use a mechanical respirator if the attendant is trained.
- If you encounter chlorine, keep your mouth closed, avoid deep breathing, keep your head high, and quickly leave the area.

Alternative Disinfectants

Slides 57-58

Chlorine Dioxide

Chlorine dioxide is a yellow-green gas with a chlorine-like odor. It is a very powerful oxidizer. It is effective against taste, odor, color, iron, manganese, or organics, and equal to or better than chlorine as a biocide. However, like chlorine, it is not effective against cryptosporidium or giardia at normal doses.

Chlorine dioxide does not produce THMs or HAAs, but does produce chlorites and chlorates, which are thought to be a health risk by EPA. The TCEQ allows no more than 0.8 mg/L of chlorine dioxide in the distribution system. At such low limits, chlorine dioxide is applicable for pretreatment, not as a final disinfectant.

Because it cannot be compressed or stored, chlorine dioxide must be generated on site, at higher cost than purchasing chlorine. Chlorine dioxide residuals are not as stable as chlorine residuals, and are more difficult to measure.

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Ozone

Ozone, a faintly blue gas, is a concentrated form of oxygen, made of three oxygen atoms instead of two. Because the third oxygen atom is very unstable, ozone is the most powerful chemical oxidizer and the most powerful chemical biocide. It is the most effective chemical against cryptosporidium or giardia.

Ozone is superior to any other chemical in oxidizing taste, odor, color, iron, manganese, or organics in water. Because of its instability, it must be produced on site (Figure 6.8). Passing an electrical current through air or oxygen generates it. This energy intensive process makes ozone the most expensive chemical disinfectant.

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Figure 6.8: Ozone generator. *Source: TEEX.*

Ozone does not produce THMs or HAAs, but can produce aldehydes, an alcohol without a hydrogen atom and bromates, a form of oxidized bromine. These byproducts are considered health risks by EPA.

The TCEQ does not approve ozone as a final disinfectant; not only because of byproducts, but also because it quickly decomposes, leaving no residual.

Slide 60

Ultraviolet Light

Ultraviolet light (UV), in certain wavelengths, is effective as a biocide. Low doses kill bacteria, viruses, and cryptosporidium. Advanced designs are having some success against giardia (Figure 6.9). UV produces no disinfection byproducts, but turbidity reduces effectiveness and systems are expensive to operate. A critical disadvantage is that UV produces no residuals.

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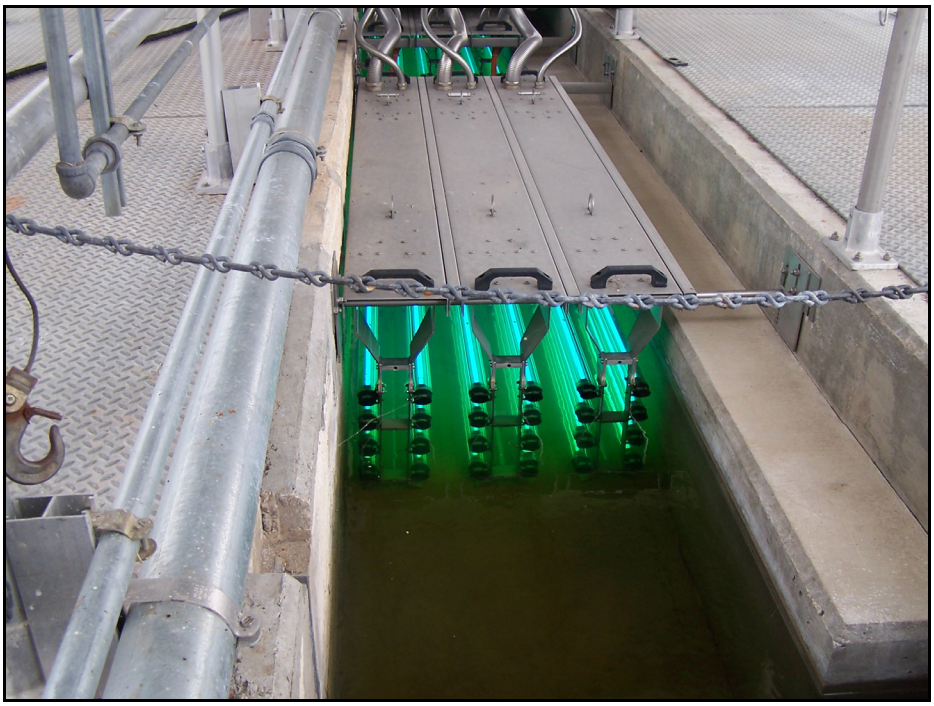

Figure 6.9: Ozone generator. *Source: TEEX.*

Summary

The use of chlorine is an acceptable method of disinfection of drinking water. Once this process is completed, the distribution system provides potable water to the public.

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Module 6 Review Questions

1. Disinfection destroys disease-causing microorganisms called pathogens.

   a. **true**

   b. false

2. Disinfection destroys pathogens without sterilizing the water.

   a. **true**

   b. false

3. Waterborne pathogens live and grow in the intestines of infected people.

   a. **true**

   b. false

4. Infected fecal matter entering a water supply transmits pathogens to healthy people.

   a. **true**

   b. false

5. Some diseases transmitted by unsafe water include typhoid, dysentery, cholera, **measles**, polio, and cryptosporidiosis.

   a. true

   b. **false**

6. Each water sample is tested for **all waterborne** diseases.

   a. true

   b. **false**

7. Water samples are tested for microorganisms that indicate fecal contamination.

   a. **true**

   b. false

8. The total coliform group of viruses are the indicators of fecal **contamination**.

   a. true

   b. **false**

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9. Fecal coliform live in the intestines of humans and warm-blooded animals.

   a. **true**

   b. false

10. The presence of fecal coliform in a water sample indicates intestinal waste is in the sample, but there is **no risk** of disease.

    a. true

    b. **false**

11. The number of **water taps** served by the system determines the minimum number of bacteriological samples.

    a. true

    b. **false**

12. The purpose of the sample siting plan is to assure bacteriological samples are taken from **vacant houses**.

    a. true

    b. **false**

13. Sodium thiosulfate is put into bacteriological sample bottles to **sterilize the water**.

    a. true

    b. **false**

14. Before taking a bacteriological sample, you should flush the service line.

    a. **true**

    b. false

15. The sample bottle should be **completely filled** with sample water.

    a. true

    b. **false**

16. The monthly bacteriological sample should be marked **"construction."**

    a. true

    b. **false**

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17. Get samples to the lab within **36** hours or they are rejected.

    a. true

    b. **false**

18. It is possible to have positive samples removed from your record.

    a. **true**

    b. false

19. It is an acute public health risk if a positive fecal coliform repeat sample or a positive total coliform repeat sample follows a positive fecal coliform routine sample.

    a. **true**

    b. false

20. Acute violations require public notification within 72 hours by radio and television using the words "**Minor** Health Concern."

    a. true

    b. **false**

21. In the event of low distribution pressure (below 20 psi), water outages, repeated unacceptable microbiological samples, or failure to maintain adequate chlorine residuals, special precautions must be instituted by the water system.

    a. **true**

    b. false

22. In Texas, all public water systems are required to have _____ facilities.

    a. ozonation

    b. **chlorination**

    c. softening

    d. trihalomethane

23. Chlorination is the most important process in the production of _____ water.

    a. public

    b. private

    c. **potable**

    d. political

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24. Besides disinfection, chlorine is used for taste and odor control and _____.
    a. oxidation of iron and manganese
    b. oxidation of hydrogen sulfide
    c. disinfection of repairs
    d. **all listed**

25. Sodium hypochlorite is liquid _____.
    a. **bleach**
    b. sodium
    c. chlorine
    d. hydroxide

26. Bleach used in public water systems must be _____ approved.
    a. AWWA
    b. TEEX
    c. OSHA
    d. **NSF**

27. Calcium hypochlorite is made by reacting chlorine with _____.
    a. sodium
    b. **lime**
    c. bleach
    d. salt

28. Calcium hypochlorite will cause explosions or fires if it contacts _____ material.
    a. **organic**
    b. inorganic
    c. suspended
    d. dissolved

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29. At room temperature, chlorine gas is greenish-yellow, has a pungent odor, is _____ times heavier than air.

    a. 2

    b. 1 1/2

    c. **2 1/2**

    d. 3

30. The maximum sustained gas withdrawal rate from 150-lb. cylinders (vacuum transmission) is _____ lb(s)./day per degree F.

    a. 4

    b. 3

    c. 2

    d. **1**

31. Disinfection capacity for drinking water must be _____% greater than the highest expected dosage.

    a. 30

    b. 40

    c. **50**

    d. 60

32. Small water systems often use _____ to disinfect their water supply.

    a. hydrochlorinators

    b. **hypochlorinators**

    c. hyperchlorinators

    d. hydrachlorinators

33. Hypochlorinators consist of a mixing tank, water, _____ hypochlorite, or _____ hypochlorite and a chemical pump.

    a. **sodium/calcium**

    b. salt/lime

    c. hydrogen/oxygen

    d. green/yellow

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34. Gas chlorinators use a rotameter to meter chlorine in _____ or grams/hr.

    a. lbs./minute

    b. lbs./hour

    c. **lbs./day**

    d. gal./minute

35. Dosage is the amount of chemical applied, demand is the amount of chemical used up, _____ is the amount of chemical remaining after reacting with demand.

    a. breakpoint

    b. chloramines

    c. **residual**

    d. combined

36. Minimum chlorine residuals of _____ (free) and _____ (combined) are required in the far reaches of the distribution system.

    a. 0.5/0.2

    b. 5/2

    c. 2/5

    d. **0.2/0.5**

37. The DPD and chlorine reaction turns the water a _____ color.

    a. green to blue

    b. **pink to red**

    c. yellow to red

    d. red to brown

38. Chlorine and water make two acids: hydrochloric (HCl) and _____ (HOCl).

    a. **hypochlorous**

    b. hypochloric

    c. hyperclorous

    d. hydrachloric

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39. A Self-Contained Breathing Apparatus (_____) must be readily available.

    a. SCUBA

    b. **SCBA**

    c. SCAB

    d. CABS

40. Chlorinator rooms must have _____-level and _____-level screened vents.

    a. window/ceiling

    b. door/floor

    c. **high/floor**

    d. low/window

41. In chlorinator rooms, _____ must be provided to determine the amount of disinfectant used and the amount remaining daily.

    a. turbidimeters

    b. pH meters

    c. color comparators

    d. **scales**

42. EPA requires any private, municipal, or industrial entity storing or using _____ pounds or more chlorine to have a chemical risk management program.

    a. 2,000

    b. **2,500**

    c. 3,000

    d. 3,500

43. Heat-sensitive pressure relief plugs in chlorine containers melt at about _____ degrees F.

    a. 140

    b. 150

    c. **160**

    d. 170

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44. Hold an open bottle of _____ ammonium hydroxide under a suspected chlorine leak.
    a. **10%**
    b. 20%
    c. 30%
    d. 40%

45. In case of leaks, the best source of help is the _____.
    a. TCEQ
    b. **supplier**
    c. EPA
    d. fire department

46. After contacting chlorine gas, wash in a safety shower or with _____.
    a. compressed air
    b. an ammonia solution
    c. **a garden hose**
    d. tanning oil

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Module 6 Presentation Slides

Basic Water Operations

Module 6
Disinfection

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Terminal Objective

- Upon successful completion of this module, the participant will be able to summarize the process for disinfection of water.

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Enabling Objectives

- Outline the processes related to the microbiological quality of water.
- Discuss the various facets of chlorination.
- Give examples of alternative disinfectants.

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Waterborne Disease

- Disinfection destroys pathogens
- Sterilization kills all organisms
- Sterilization not necessary
- Most microorganisms in water nonpathogenic
- Intestinal waste contamination transmits pathogens

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Revised Total Coliform Rule

- Effective 4/1/16
- Total coliforms
  - not harmful
  - useful indicator of
    - Pathogens
    - Adequate water treatment
    - Distribution system integrity

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Revised Total Coliform Rule

- Key provisions
  - Maximum level of *E.coli*
  - Total coliform treatment technique
  - Total coliforms, *E.coli* monitoring requirements
  - Provisions for transition to RTCR
  - Seasonal system requirements
  - Assessments, corrective action for possible contamination
  - Public notification requirements
  - Consumer Confidence Report language

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Diseases Transmitted by Unsafe Water

- Typhoid/paratyphoid
- Dysentery
- Hepatitis
- Gastroenteritis
- Cholera
- Others

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Indicator Organisms

- Pathogens difficult to detect
- Samples tested for fecal contamination
- Coliform group - indicator microorganism
  - Non-fecal—soil
  - Fecal—intestines
    - *E.coli* most specific indicator, cause of disease

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Indicator Organisms

- Fecal coliform/*E.coli* in water sample = disease potential
- Only dangerous if intestinal source was infected with pathogens
- Impossible to know if source was infected or healthy

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Indicator Organisms

- MCL for microbial or bacteriological contaminants in public water systems:
  - 290.109
  - Based on presence/absence of *E.coli.*

Monitoring Requirements

- Collect samples for microbial contaminants
  - Total coliform
  - Fecal coliform
  - *E.coli* or other approved fecal indicator
- Locations:
  - Customer's premise
  - Dedicated sampling station
  - Other designated compliance sampling location

Monitoring Requirements

- Frequency
  - Sample number based on residential population served
  - Sample throughout month
    - PWS using surface water or groundwater under influence of surface water
    - PWS using purchased or ground water only, serving more than 4,900 people

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Monitoring Requirements

- Sample on single day (different sites)
  - Purchased or ground water only, serving less than 4,900 people
- May collect more than minimum required samples, but must include them in calculations.

Bacteriological Sampling

- Important operator responsibility
- How to collect samples
  - Determine number of samples required (Table 6.1)
  - Develop a written sample siting plan (community or non-community system)

Community Water System Procedures

- Select representative site
- Consider various mains
- 5 samples or less – 5 sites
- Give descriptive address
- Make sites easily noted and explainable
- Required site listing information

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Non-Community System Procedures

- Maximum daily population for required samples
- Businesses select one point representing plumbing
- Recreation areas develop plans as community
- Locate sites on distribution map
- List sites as would community systems (Table 6.2)

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Sample Siting Requirements

- Include all groundwater sources
- Include all repeat sample site locations, other sampling points.
- Required SOP for proposed repeat sampling sites.

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Sample Siting Requirements

- Distribution system map identifying
  - Valves and mains
  - Routine sample sites
  - Water main sizes
  - Entry point course locations
  - Water storage facilities
  - Pressure plane boundaries.

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Sample Siting Requirements

- Keep updated
- Maintain copy at public water system for inspection
- Provide copy to executive director upon request

How to Collect Samples

- Collecting Bac-T samples
  - Obtain sample containers
  - Sample from designated sites
  - Flush the service line
  - Test chlorine residual
  - Flame or disinfect the faucet

How to Collect Samples

- Collecting Bac-T samples (cont.)
  - Fill sample container
  - Complete sampling form
  - Send to laboratory within 30 hours
  - Sterile container with sodium thiosulfate
  - Don't overfill container
  - State type of sample

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Positive Samples

- Collect at least 3 repeat samples
  - within 24 hrs. or ASAP if lab closed (executive director may extend 24-hr. limit)
  - On same day (single-service connection-3 days)
  - 1 repeat sample at original positive sample site
  - 1 repeat sample within 5 connections upstream and downstream
  - If positive sample at system end, 1 repeat sample there; all others within 5 connections upstream

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Positive Repeat Samples

- PWS must collect another sample from same location as original sample within 24 hours notification, or ASAP if lab is closed, and have analyzed for total coliform.
- Repeat process until
  - Total coliforms are not detected in one complete set of repeat samples; or
  - A coliform treatment technique trigger has been exceeded.

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Invalidating Positive Samples

- Executive director may invalidate if
  - Results caused by domestic or other non-distribution plumbing problem
  - Total coliform-positive result due to condition/ circumstance that does not reflect water quality in distribution system.
  - Lab provides written notice that improper sample analysis caused the total coliform-positive result or that the sample was unsuitable for analysis

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Evaluating Results

- A PWS is in compliance unless
  - Fails to submit required routine/repeat samples
  - Fails to report positive sample results or post required public notice
  - Has *E.coli*-positive repeat sample following total coliform-positive routine sample
  - Has total coliform-positive repeat sample following *E.coli*-positive routine sample
  - Fails to take all required repeat samples following *E.coli* positive routine sample
  - Fails to test for *E.coli* when any repeat sample tests positive for total coliform

Level 1 Treatment Triggers

- Public Water System
  - Collects 40+ samples a month: more than 5% total coliform positive
  - Collects >40 samples a month: 2 or more total coliform positive
  - Fails to collect all required repeat samples after total coliform-positive result

Level 2 Treatment Triggers

- *E.coli* MCL violation-subsection (b)(1)(A)-(D)
- A second Level 1 treatment technique trigger occurs within rolling 12-month period.
  - If problem has been corrected, not required to conduct Level 2 assessment.
  - Must still conduct required Level 1 assessments

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Treatment Technique Assessment

- Assessors
  - Public water system
  - Licensed operators
  - Other parties approved by executive director
    - Licensed backflow prevention assembly testers and customer service inspectors
    - Plumbing inspectors, water supply protection specialists
    - Licensed professional engineers
    - Circuit riders or technical assistance providers
    - Utility supervisor or manager

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Treatment Technique Assessment

- Review and identify inadequacies in
  - Sample sites
  - Sampling protocol
  - Sample processing
  - Events that could affect water quality
  - Changes to distribution system maintenance
  - Source/treatment factors affecting water quality
  - Existing water quality monitoring data

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Treatment Technique Assessment

- Level 1 assessment completed/submitted
  - As soon as possible
  - Never more than 30 days after learning a trigger was exceeded

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Treatment Technique Assessment

- If executive director deems Level 1 insufficient
  - PWS consults with executive director
  - PWS submits revised assessment within 30 days of consultation
  - Executive director determines if trigger cause was identified/corrected
- The process for Level 2 assessments is the same

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Treatment Technique Assessment

- For Levels 1 and 2, PWS's must:
  - Correct sanitary defects
  - Complete corrections in compliance with approved timetable
  - Notify executive director when corrections complete

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Public Notification

- Procedure decided by TCEQ
- Always consult TCEQ before notifying public
- Acute violation
  - Within 24 hours using "Serious Health Concern"
- Non-acute violation
  - Within 14 days using "Possible Health Concern"

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TCEQ Special Precautions

- Instituted in event of
  - low distribution pressures
  - Water outages
  - Repeated unacceptable microbiological samples
  - Failure to maintain adequate chlorine residuals
- Determine necessary action (Figure 6.2)
- Boil water notice (Figure 6.3)

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Chlorination

- Disinfectant Purposes
  - Stored water must have disinfectant residual. Disinfectant **must** be present in drinking water
  - Controls taste and odor
  - Oxidation of iron/manganese/hydrogen sulfide
  - Disinfection of repairs

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Chlorination

- Effectiveness of Disinfection
  - Concentration of the disinfectant
  - Contact time of the disinfectant with the water being treated
  - Temperature of the water
  - pH of the water
  - Other factors: turbidity, amount and type of demand, and type of residual being used

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Chlorine Sources

- Hypochlorites
  - Sodium hypochlorite (liquid bleach)
  - Calcium hypochlorite (granular/powder)
- Pure Chlorine
  - Produced by electrolysis of brine
  - In common table salt

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Chlorine Sources

- Pure Chlorine (cont.)
  - Sodium hydroxide, hydrogen gas are byproducts
  - Becomes amber-colored when cooled
  - CHLORINE GAS IS TOXIC!
  - Commonly shipped in 150 lb. cylinders/ton containers

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Chlorine Safe Withdrawal Rates

- Vacuum withdrawal
  - 150 lb. cylinder – 1 lb./day per degree F
  - Ton container – 8 lbs./day per degree F
- Pressure transmission
  - 150 lb. cylinder – 42 lbs./day at 70°F
  - Ton container – 336 lbs./day at 70°F

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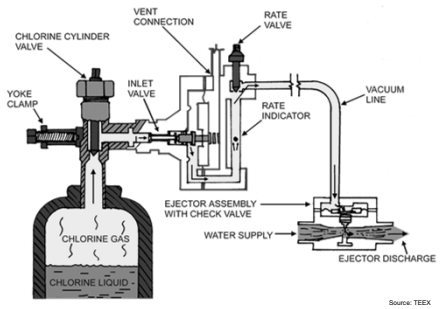
Chlorination Techniques

- Hypochlorination
  - Mixing tank
  - Water, sodium or calcium hypochlorite
  - Meter-paced or manually controlled pump
  - Solution strength adjusts chemical amount
  - Usually used by small systems

Chlorination Techniques

- Gas Chlorination
  - Chlorine enters through inlet valve
  - Powered by water
  - Gas metered through a rotameter
  - Enters flow controller and suctioned into injector
  - Mixed with water, then applied

Gas Chlorination



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Dosage, Demand, and Residuals

- Dosage = chemical applied (mg/L or ppm)
- Demand = chemical used up by reducing agents
- Residual = chemical remaining after reaction with demand
- Dosage = Demand + Residual

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Types of Residuals

- Free residual
  - Chemically uncombined
- Combined residual (chloramine residual)
  - Chemically combined
- Total residual
  - Free residual and combined residual

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Residuals

- Minimum residual requirements
- Maximum residual requirements
- Testing for chlorine residual
  - Measuring devices
  - Methods (Appendix C)

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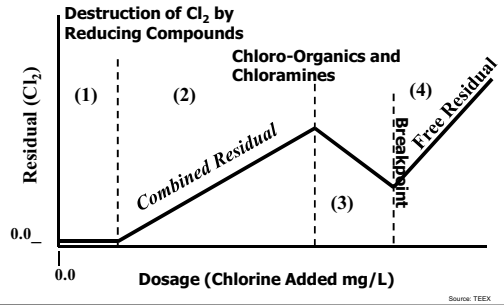
Chlorine Reactions In Water

- Chlorine gas with water forms two acids
  - Hypochlorous acid – the disinfectant
  - Hydrochloric acid
- When chlorine demand met, taste/odor may remain
- When free residual remains, taste/odor dissipate

Chlorine Reactions In Water

- Reducing Agents
  - React with chlorine, reducing/destroying disinfecting power
    - Ammonia
    - Iron
    - Manganese
    - Hydrogen sulfide
    - Bacteria
    - Organic compounds

Chlorine Demand Curve



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Formation of Chloramine

- Chlorine + ammonia = chloramine
  - Monochloramine (desired)
  - Dichloramine (chlorine overfeeding, bad taste)
  - Trichloramine (higher feed rate, bad odor)

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Formation of Chloramine

- Adding ammonia results in only monochloramine forming
- Leads to nitrification (converting ammonia to nitrite and nitrate).
- To reduce nitrification
  - Optimize chloramination process
  - Reduce water age in system
  - Conduct routine system maintenance (high-flow flushing, pigging)
  - Replace aging pipes

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Chlorine Safety

- Chlorinator rooms and equipment
  - Disinfection equipment capacity of >50%
  - Housing above ground
  - Equipment and containers stored separately
  - High-level and floor-level screened vents
  - Forced air vents in 150 lb. cylinder rooms

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Chlorine Safety

- Chlorinator rooms and equipment (cont.)
  - Store chlorine between 50-140°F
  - Scales available for daily usage
  - Hypochlorination solution equipment locked
  - Solution container must be covered

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Chemical Risk Management

- Required by EPA
  - Any private, municipal, or industrial entity
  - If 2,500 lbs. or more are stored/used
- Required by the TCEQ
  - Establish evacuation procedures
  - 1 ton of chlorine/ammonia or more
  - Within 1/4 mile of dense population

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Chlorine Leaks

- Detect using 10% ammonium hydroxide
- Ammonium chloride appears as white smoke
- Take precautions before entering chlorine room
- If necessary, contact supplier for info

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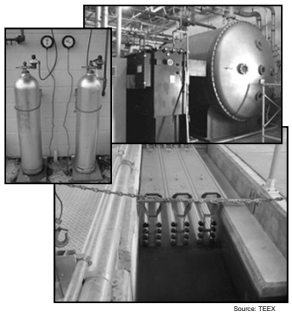
Entering a Chlorine Room

- Be trained and prepared
- Wear a fresh air supply
- Have standby help
- Have repair equipment
- Wear safety harness and lifeline

First Aid

- Fresh, warm air, and sit or lie down
- Call medical help
- Wash skin, clothing in safety shower
- 15-minute eye flush with cool water
- Coffee, tea, milk, or peppermint candy
- Artificial respiration, if necessary

Alternative Disinfectants



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Alternative Disinfectants Chlorine Dioxide

- Yellow-green gas, chlorine odor
- Effective against taste, odor, color, iron
- Produces chlorites and chlorates
- 0.8 mg/L allowed by TCEQ
- Applicable for pretreatment
- Higher cost/difficult to measure

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Alternative Disinfectants Ozone

- Faint blue gas, 3 oxygen atoms
- Most powerful chemical oxidizer/biocide
- Superior oxidation for taste, odor, color
- Most expensive chemical disinfectant
- Can produce aldehydes
- Not approved by TCEQ for final disinfection

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Alternative Disinfectants Ultraviolet Light

- Effective as a biocide
- Low doses kill bacteria, viruses, cryptosporidium
- Produces no disinfection byproducts
- Produces no residuals

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Module 6

Review Questions

End of Module 6

Next Module: Distribution

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Module 7

Distribution

Terminal Objective

Upon the successful completion of this module, the participant will be able to describe the common methods of water delivery to the public following water treatment.

Enabling Objectives

1. Discuss the different types of storage.
2. List the major components of the distribution system.
3. Explain the different aspects of pump usage for distribution.
4. Discuss the use of motors in distribution system pumps.

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Instructional Guidance

Time

2 hours, 50 minutes

Materials/Equipment

1. Participant manual
2. Laptop with presentation slides for module 7
3. Internet connectivity
4. Video/data projector
5. Screen or monitor

Instructor Preparation

Prepare projector and position first presentation slide.

Application of Participants' Knowledge/Skills

Have participant complete the review questions at the end of the module.

Evaluation of Participants

Go over the review questions at the end of the module, answering any questions the participant may still have.

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Introduction

Slides 1-4

Storage facilities equalize demand on the water supply. When demand for water is low, storage will be filling. During peak water demand, storage will begin to empty. Storage:

- allows uniform pumping rates;
- supplies water for firefighting; and
- provides time for disinfection.

Storage Reservoirs

Types of Storage

Ground Storage

Slide 5

Ground storage is generally constructed of reinforced concrete or steel, and placed after production and ahead of distribution (Figure 7.1). Ground storage at a surface water treatment plant receiving the treated water is called a clear well.

Figure 7.1: Ground storage. *Source: TEEX*

The TCEQ requires all storage tanks to have screened vents, locked hatches, a dust-proof cover, overflows with hinged flaps, and entry ports. Screens must be made of corrosion-resistant material 16-mesh or finer. Overflow covers must have no gap greater than 1/16 inch. The rim of the entry port must extend at least four inches above the tank and have a lid with a two-inch overlap to prevent rain from entering. If ground storage is the only storage, capacity must be 200 gallons per connection. Otherwise, total storage capacity (elevated storage included) must be 200 gallons per connection.

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Slide 6

If a 30-inch diameter access opening is not provided in a storage tank, the primary roof access must not be less than 30 inches. An existing tank without a 30-inch access opening must be provided with one when major maintenance is performed on the tank.

Storage tanks must be painted, disinfected, and maintained according to AWWA standards. No paint, coating, or wax containing lead is allowed. Coatings for contact with potable water must be approved by EPA, National Sanitation Foundation (NSF), or the U.S. Food and Drug Administration.

Slide 7

Elevated Storage

An elevated storage tank is usually constructed with steel and supported aboveground on a tower (Figure 7.2). Pressure is maintained by the height of the water column. The taller the water column, the more weight and the more pressure. Each foot of a water column produces 0.433 psi.

Figure 7.2: Elevated storage. *Source: TEEX*

The TCEQ considers elevated storage as water stored at least 80 feet above the highest service connection. Such elevation provides pressure that meets the state minimum normal operating pressure of 35 psi.

Elevated storage is required for systems with more than 2,500 connections and capacity must be 100 gallons per connection. Elevated storage must meet the same general design criteria as ground storage.

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Slide 8

Standpipes

A standpipe is a tank resting on the ground that is greater in height than diameter. A standpipe is considered ground storage unless it exceeds 80 feet above the highest service connection (Figure 7.3).

Figure 7.3: Standpipe storage.
Source: TEEX

Standpipes are usually built on elevated ground where an 80-foot tower is unnecessary.

Standpipes must meet the same general design criteria as elevated storage.

Slide 9

Pressure Tanks

Pressure tanks (hydropneumatic tanks) are cylindrical and horizontal to the ground. Air mechanically compressed against the water surface provides pressure (Figure 7.4).

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Figure 7.4: Pressure tank. *Source: TEEX*

Pressure tanks are used in mobile home parks, subdivisions, resorts, and some rural water systems to maintain pressure in distribution. In some cases, pressure tanks can substitute for elevated storage.

A water system without ground storage (less than 50 connections) must have a pressure tank capacity of 50 gallons per connection. A system with ground storage is allowed pressure tank capacity of 20 gallons per connection, or elevated storage.

Storage Maintenance

Slide 10

Annual Inspections Required

The exterior and interior of ground, elevated, standpipe, and pressure tanks must be inspected yearly by water system personnel or a contracted service. Inspection results must be documented and kept at least five years.

Inspections determine if the tanks are watertight, are not accumulating interior sand or chemicals, and have screened vents, locked roof hatches, and flap valves that properly seal.

The exterior and interior coating must be inspected for corrosion protection. The interior coating must meet AWWA specifications.

Protecting Tanks Against Corrosion

Besides coatings, additional means of corrosion protection are:

- cathodic protection,
- water conditioning, and
- galvanizing (not for elevated tanks).

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Cathodic protection is an electrochemical method for preventing corrosion of the interior of metal tanks. Direct current travels through strips or rods of aluminum or other conductive metal. The strips/rods are suspended in the tank, then through the water, thus electroplating the walls below the waterline. Metal above the waterline is not protected.

Water conditioning involves adding chemicals to make the water less corrosive or applying a protective coating on the tank walls.

Ownership Signs

Ownership signs must include the utility name and emergency phone number at each production, treatment, or storage site.

Grounds and Landscaping

The TCEQ requires utilities to have a program to facilitate cleanliness and improve the appearance of plant sites.

The grounds must be sloped away from the tank or tower to prevent collection of surface water that can cause contamination and weaken foundations.

Chain link fence material must be flush with the ground, without a gap.

Sanitary Protection

Slide 11

The state requires stored water to have a disinfectant residual.

If a tank is wholly or partially underground, it cannot be located near potential contaminants such as sewer lines, septic tank drain fields, animal feed lots, or areas prone to flooding.

Cracks and leaks must be repaired as soon as possible.

Sunlight (causes algae growth), dust, birds, insects, and rain are contaminants and must be prevented from entering the tank.

Storage tanks must be disinfected after construction or maintenance. After a tank is disinfected, a sample must be collected for bacteriological analysis. If the sample is negative, the tank may be placed into service. If the sample is positive, more samples must be taken until two consecutive samples are negative. If samples continue to be positive, repeat the disinfection process.

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The Distribution System

Slide 12

The distribution system consists of water mains, service lines, meters, valves, hydrants, and pressure booster pump stations. The system must meet standards for water quality, quantity of water, pressure, and fire protection.

Critical safeguards of a distribution system include a minimum chlorine residual, adequate pressure, monthly bacteriological sampling, and cross-connection control programs.

The TCEQ requires distribution system pressure to never fall below 20 psi, even during emergencies. TCEQ rules and regulations for operating a water distribution are found in 30 TAC Chapter 290.44. These regulations can be downloaded from the TCEQ website in either MS Word or PDF format. Chapter 290.44(d) contains the TCEQ rules for distribution system pressure. Note that distribution system pressure should never fall below 20 psi, even during emergencies. Under normal operating conditions, the distribution pressure must be at least 35 psi. Adequate pressure prevents contaminated water from being drawn into and throughout the system.

Components of the Distribution System

Slide 13

Material used in water line construction must meet the AWWA specifications and should not affect the taste, odor, or quality of the water.

Pipe Material

Pipe can be ductile iron, cast iron, steel, asbestoscement, concrete, Polyvinyl Chloride (PVC), or copper. Asbestos-cement pipe is not allowed in Texas for new construction in potable water systems. Plastic pipe must be NSF (National Sanitation Foundation) approved and have an ASTM (American Society for Testing and Material) pressure rating of at least 150 psi or a standard dimension ratio of 26. No pipe used for any purpose other than drinking water is acceptable in a public supply.

Select pipe on the basis of strength, carrying capacity, durability, ease of installation, availability, soil conditions, and cost.

Lead ban: According to the TCEQ and EPA, pipe and fittings containing more than 8.0% lead, or solders and flux containing more than 0.2% lead, are prohibited in a public water supply or in plumbing connected to a public water supply.

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However, the Reduction of Lead in Drinking Water Act was enacted on January 4, 2011 to amend Section 1417 of the Safe Drinking Water Act (SDWA or Act) respecting the use and introduction into commerce of lead pipes, plumbing fittings or fixtures, solder and flux. The Act established a prospective effective date of January 4, 2014, which provided a three-year time frame for affected parties to transition to the new requirements.

The new definition of "lead free" will be:

> (A) not containing more than 0.2 percent lead when used with respect to solder and flux; and
>
> (B) not more than a weighted average of 0.25 percent lead when used with respect to the wetted surfaces of pipes, pipe fittings, plumbing fittings, and fixtures.

Pipe Joints

Pipe joints are either flanged, mechanical, push-on, welded, or threaded. Gasket material should prevent bacterial growth.

Slide 14

Valves

The purpose of water valves is to control water flow. The manner in which a valve accomplishes this task depends on the valve type or classification. A valve classified by function is used for isolation or control.

Isolating valves cut off sections of a system. An isolation valve is designed to prohibit or permit the flow of water. An isolation valve can be either closed or open, and is not generally used to throttle water flow. Most distribution valves are isolation valves.

Classification by design includes slide, rotary, globe, diaphragm, and special valves.

Slide valves include gate, sluice gate, and shear gate valves. Sluice gate and shear gate valves are used for flow control in water treatment plants.

Rotary valves used in the distribution system include butterfly, cone, and ball valves.

Globe valves have a flat or tapered disk of resilient material that lowers onto a seat to stop or restrict flow, giving it a wide range of pressure and flow settings. The typical household faucet is a globe valve.

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Inside a diaphragm valve is a piece of flexible material that is attached to the circumference of the valve body. To regulate or stop the flow of water, the flexible material (diaphragm) is pressed onto the valve seat by an operating stem. When the stem is raised, flow is restored.

There are many valves that do not fit the discussed classifications. These are referred to as special valves. Examples of these categories are the swing check valve, the silent check valve, and the air/vacuum relief valve. The most commonly used is the gate valve.

A control valve regulates pressure, volume, or flow direction. Flow pressure and volume may be regulated by throttling the valve. Control valves include globe, altitude, check valves, diaphragm, and rotary valves. One way to control flow direction is by using a swinging flap found in a check valve. Check valves are installed on the discharge side of pumps to prevent backflow when the pump is off. A control valve that is set or adjusted by differential pressure is called an automatic control valve. Pressure-regulating valves are often globe valves that reduce water pressure by restricting the flow through it.

Slide 15

Fire Hydrants

Other than firefighting, an important use of hydrants is flushing. Flushing can assist in solving problems such as taste and odor, red water, dirty water, or bad samples. Hydrants can be used to bleed air from mains after construction or repair (Figure 7.5).

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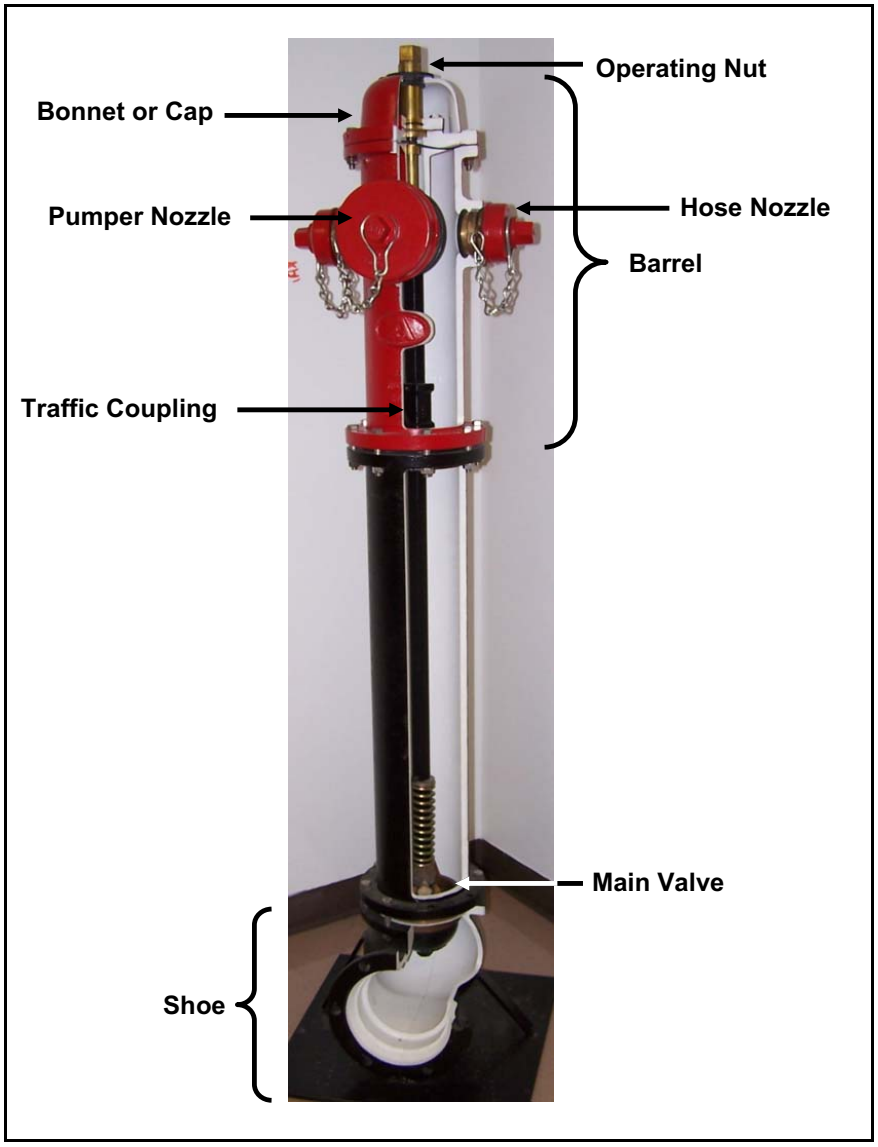

Figure 7.5: Fire hydrant cutaway. *Source: TEEX*

Slide 16

Meters

Meters measure the flow of water into and out of treatment plants, into the distribution system, and to customers. Propeller, compound, and magnetic meters are common designs. The positive displacement meter is the most common design for residential use (Figure 7.6). It is very accurate at low flows and cannot over register from external influence or the internal wearing of the meter components.

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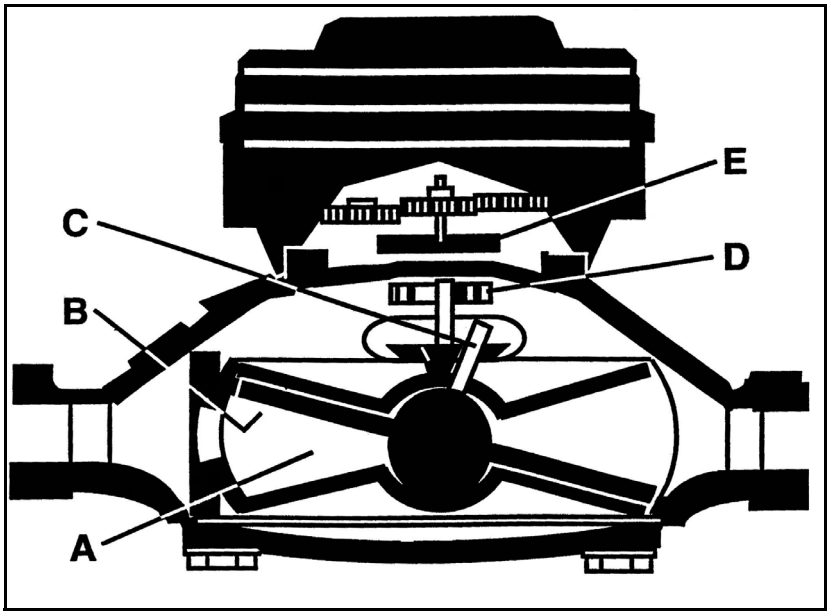

Figure 7.6: Positive displacement, nutating disk water meter.
Source: Badger Meter, Inc.

Water flowing through the meter chamber (A) causes a disc (B) to nutate or wobble. This motion, in turn, results in the rotation of a spindle (C) and drive magnet (D). Rotation is transmitted through the wall of the meter to a second magnet (E) that operates the register.

Pipe Installation

Slide 17

Main Installation

Water mains must be no closer than nine feet, in all directions, from sewers or manholes. Distances are measured from the outside surface of each pipe. Parallel water and sewer lines must be laid in separate ditches. When the nine-foot separation cannot be achieved, refer to TCEQ regulation 30 TAC 290.44(e)(5).

The piece of pipe material cut from a main when a tap is made is called a coupon.

Trenches for laying 6-inch or larger pipe must be a minimum of 18 inches wide and 12 inches wider than the pipe diameter. Main depth depends on frost lines, surface load, and obstructions. In Texas, 30 to 60 inches is the rule, but the top of the pipe must have at least 24 inches of cover.

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Service Line Installation

The valve that connects the service line to the main is called the corporation stop. It is buried when the hole is backfilled and cannot be operated from the ground surface. The valve that connects the service line to the meter is called a curb stop or meter stop. It can be operated from the meter box.

Trench Safety

Slide 18

Do not work in a ditch five feet or deeper unless it is protected from cave-ins. The life you save may be your own!

Cave-ins are likely when:

- the soil is wet,
- spoil banks are too close to the trench, or
- traffic or machinery vibrations loosen the soil.

Use of timber, plywood, or commercial devices to support an excavation is known as shoring (Figure 7.7).

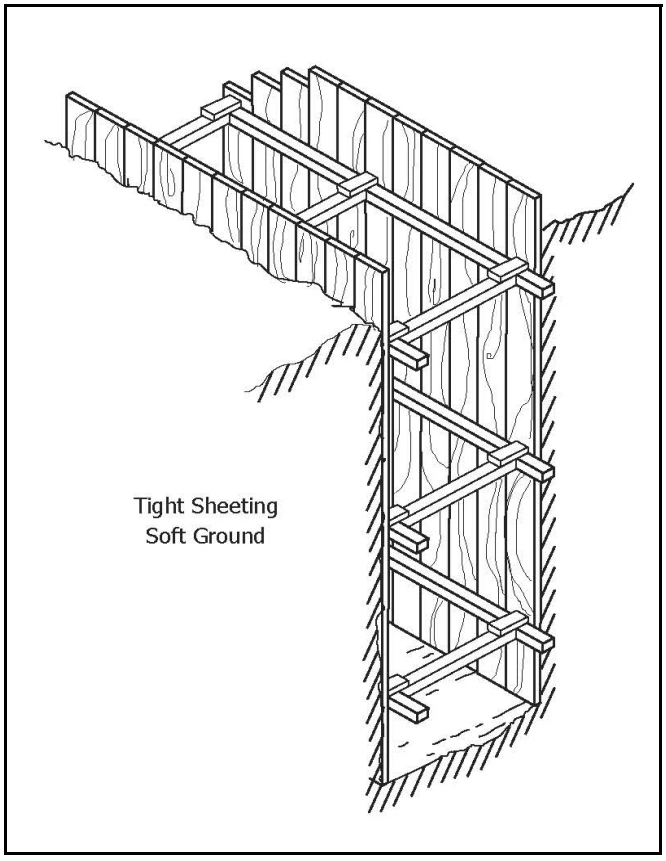

Figure 7.7: Trench shoring. *Source: TEEX.*

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If shoring is used, it is installed from the top down and removed from the bottom up. Shoring should be inspected daily by a competent person. If problems arise, such as subsidence or soil cracks, stop work immediately and correct the problem.

Shoring is not necessary if the trench walls are sloped to the maximum allowable slope, which is the degree of slope that overcomes collapsing pressure. The slope is determined by soil conditions.

Trench boxes may be used in place of shoring, but workers must stay in the box to be protected. Place spoil banks at least two feet from the excavation.

Slide 19

Pipe Bedding

Pipe must be bedded with a minimum of four inches, or 1/4 of the pipe diameter, of tamped sand or gravel (Figure 7.8). When the pipe is in place, backfill the trench carefully.

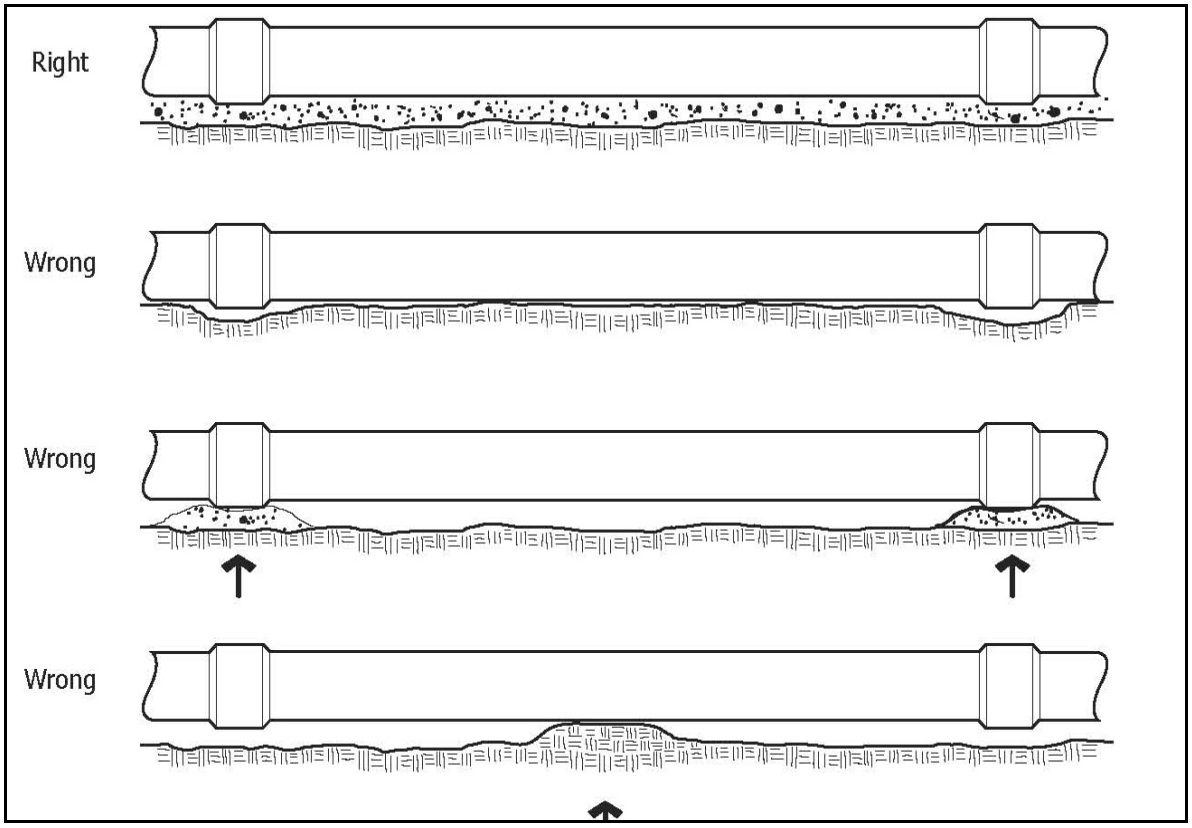

Figure 7.8: Pipe bedding. *Source: TEEX*

Pipe Bracing

Slide 20

Wherever the line changes direction, the bend must be braced or blocked against internal thrust. At 60 psi, there is almost 1,700 lbs. of thrust against a closed six-inch valve.

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Sanitation

Slide 21

Trenches should be kept as clean and dry as possible. Ditch water should not be allowed to enter the pipe. Installation crew must never use the trench as a latrine.

To maintain sanitary conditions, swab pipe with a hypochlorite solution as it is laid in the trench. Never leave installed pipe with an open end. Cap it with a watertight plug.

Disinfection

Slide 22

AWWA standard C651-92 provides three methods of chlorination for water mains: tablet, continuous, and "slug." The chlorine dose and minimum contact time for each AWWA method is summarized in the table below (Table 7.1). Recommendations for disinfection of small sections of mains under emergency repair are also included in the table below. Before any disinfection method is utilized, valves must be positioned so that the highly chlorinated water in the main being treated does not flow into water mains in active service. When it is necessary to return repaired mains to service as rapidly as possible, doses may be increased to 500 mg/L and the contact time reduced to 1/2 hour.

Table 7.1: AWWA Standard C651-92 Chlorination Methods

Chlorination Methods for Disinfection of Water Mains			
Chlorination Method Used	**Initial Chlorine Dosage (mg/L)**	**Minimum Contact Time (Hours)**	**Minimum Chlorine Residual (mg/L)**
Nonemergency Procedures			
Tablet	25	24	10
Continuous	25	24	10
Slug	100	3	50
Emergency Procedures			
Premixed solution or Hydrochlorite injection	300	0.25	100
Swabbing	10,000 (1% Solution)	N/A	Swab thoroughly the interior of pipes and fittings used in repairs

After the new or repaired line is disinfected, flush the line to discharge the excess chlorinated water.

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Do not place a new main into service until a bacteriological sample is analyzed and shows negative results. One sample is required for each 1,000 feet of completed main.

Maintenance of Distribution Systems

Flushing

Slide 23

Dead-end mains must be flushed once a month. Flushing reduces slime and scale buildup, reduces red water complaints, brings fresh chlorinated water to contaminated areas, and reduces chlorine-reducing materials from the distribution system.

Flush carefully! Pressure surges created by rapid flow changes, such as closing a hydrant valve too quickly, cause water hammer and possible extensive damage to mains.

Scale

Slide 24

Tuberculation is a buildup of oxidized iron, calcium carbonate, or other chemicals in mains. High-pressure water, pigs or swabs, and chemicals are methods of removing scale.

Corrosion

Corrosion is the dissolving of metal. Corrosion will damage pipe and storage tanks and affects water quality. Corrosive water may become discolored with rust, resulting in an unpleasant taste. Corrosive water may contain harmful amounts of lead, copper, or other metals.

Slide 25

Factors that make water more corrosive are as follows:

- Low pH
- Dissolved oxygen and carbon dioxide
- Dissolved salts
- Free chlorine
- Low hardness

Slide 26

- High velocity
- High temperature
- Low alkalinity
- Sulfate-reducing bacteria

If the water is red, but not corrosive, the cause could be iron bacteria.

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Slide 27

Corrosion is controlled by using pipe with protective linings or coatings, installing anodes in storage tanks, eliminating different metals (galvanic corrosion) in the distribution system, and treating the water with chemicals.

Galvanic corrosion occurs when different metals, such as copper and steel, are connected. Dielectric (nonconducting) unions should be used to separate metals.

Main Repairs

Slide 28

Main breaks are a challenge to any utility. Crews must be supplied with tools, repair materials, maps of the distribution system, pipe location equipment, safety equipment, traffic control devices, and first aid supplies. Backhoes, pumps, and air compressors should be stored at a service center.

Slide 28

When the leak is found:

- excavate below the pipe on both sides, allowing repair materials to be easily set;
- dig one side deeper to form a pump sump; and
- reduce contamination risk by keeping pooled ditch water out of the pipeline.

Slide 29

When possible, repair the leak "hot"—without turning off the valves. Working the leak under pressure has the following advantages:

- Eliminates interrupted service
- Reduces risk of contamination
- Reduces air in the main
- Ensures the repair holds under service

Proper cleanup is important for good public relations. Paving, sidewalks, and driveways must be replaced. Lawns, trees, and shrubs must be restored. Assure that you do not promise residents what is not a utility policy.

Cross-Connection Control

Slide 30

A cross connection is a physical connection between a public water system and:

- another supply of unknown or questionable quality,
- any source that may contain contamination, or
- any water treated to a lesser degree.

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Typical cross connections are bottom connections to stock tanks, lawn-sprinkling systems, faulty pump installations, piping from a private well connected to a house with city water, and pump priming.

Valves or check valves are not safe between a potable and unknown water supply. The air gap is the preferred method to prevent cross connections and is the only method approved by the TCEQ for protection against sewage contamination.

In certain situations, the TCEQ allows backflow prevention devices if properly located, maintained, and inspected.

AWWA standards list and discuss backflow prevention devices such as atmospheric vacuum breakers, double check valve assemblies, and reduced pressure devices.

Instructor Note

Facilitate a discussion on operator experiences with cross connections in a system. The following is a response from an operator: We had a water hose in a bucket with chemicals. There was a leak downstream and the water was siphoned into the system.

Emergency Preparedness

Slide 31

In addition to maintenance, be prepared for emergencies. When an emergency situation arises, repair manuals need to be available and spare parts should be on hand.

When severe storms are expected the water utility should:

- alert personnel;
- check communications;
- fill gasoline tanks;
- check emergency equipment;
- fill storage tanks;
- isolate elevated storage;
- restock repair clamps and calcium hypochlorite; and
- review emergency procedures.

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Pumps

Centrifugal Pump

Slides 32-33

This is the most common pump in the water utility industry, although it is not the best pump for every situation (Figure 7.9). To be efficient, the centrifugal pump must be designed for a particular job.

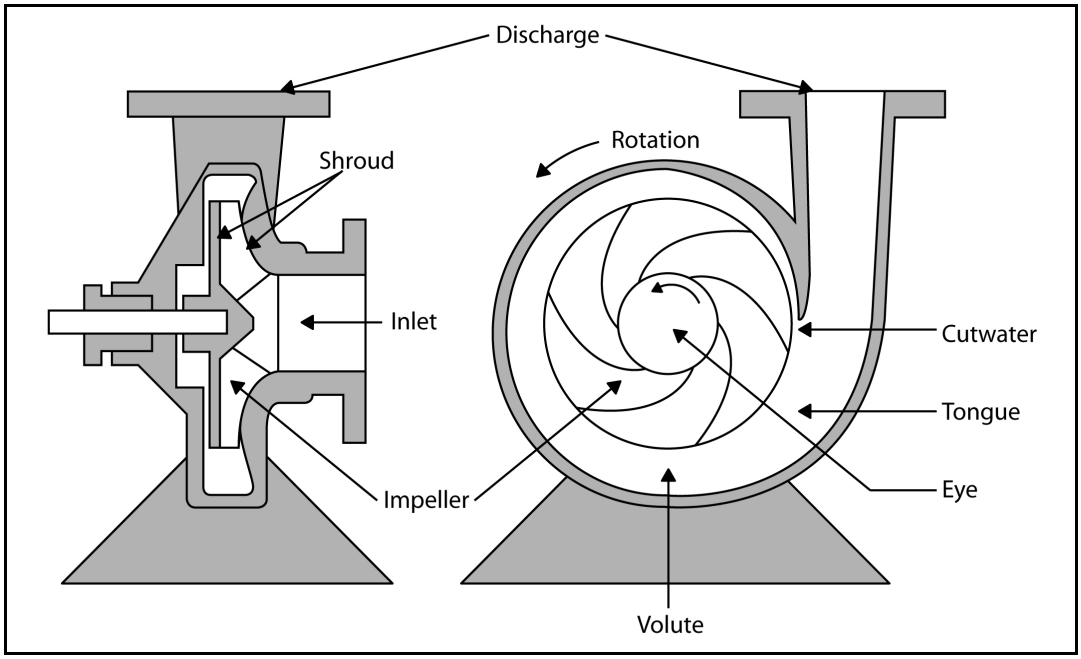

Figure 7.9: Centrifugal pump diagram. *Source: TEEX*

The centrifugal pump is first primed by filling the volute with water. The volute is the casing enclosing the impeller (Figure 7.10).

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Figure 7.10: Centrifugal pump. *Source: TEEX*

The motor is energized and the impeller spins, throwing water out of the volute by centrifugal force. Water is supplied to the pump by atmospheric pressure (suction lift) or by the weight of the water (suction head).

Deep-Well Turbine

Slide 34

A type of centrifugal pump used in water wells is the deep-well turbine. Vertical impellers move the water from one stage to the next. The pumps are either oil or water lubricated. Before starting a water-lubricated pump, the water line must be on.

Centrifugal Pump Selection

Slide 35

Pump selection for a particular system depends on several factors:

- Amount of water to be pumped
- Force (head) the pump works against
- Material to be pumped
- Cost
- Availability
- Pump efficiency

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Pump capacity is the output of the pump expressed as gallons per minute (gpm). With a centrifugal pump, the capacity changes as the head (pressure) the pump works against changes. This relationship is inverse. If head pressure goes up, gpm output goes down. When examining the performance of a given pump, its head, output, and efficiency should be calculated.

Pumping Rate

Slide 36

Pumping rate is expressed in gallons per minute or, in very large pumps, million gallons per day.

Head

Head is the force the pump works against. Static head is measured in feet or psi. When there is no flow or pumping, the head is "static." When there is flow or pumping, the head is "dynamic."

Slide 37

Suction lift. Vertical distance water is raised from supply to the pump centerline

Suction head. Vertical distance water supply is above the pump centerline

Discharge head. Vertical distance between pump centerline and free discharge

Total static head. Vertical distance between supply and free discharge

Friction head. Force to overcome resistance in pipe and fittings

Total dynamic head. Total static head + friction head

Pump Curves

Slides 37-38

A pump curve assists in selecting a pump (Figure 7.11). Three types of curve:

Head capacity curve. Relationship between total head and gallons per minute

Efficiency curve. Relationship between pump efficiency and gallons per minute

Horsepower curve. Relationship between gallons per minute and horsepower required

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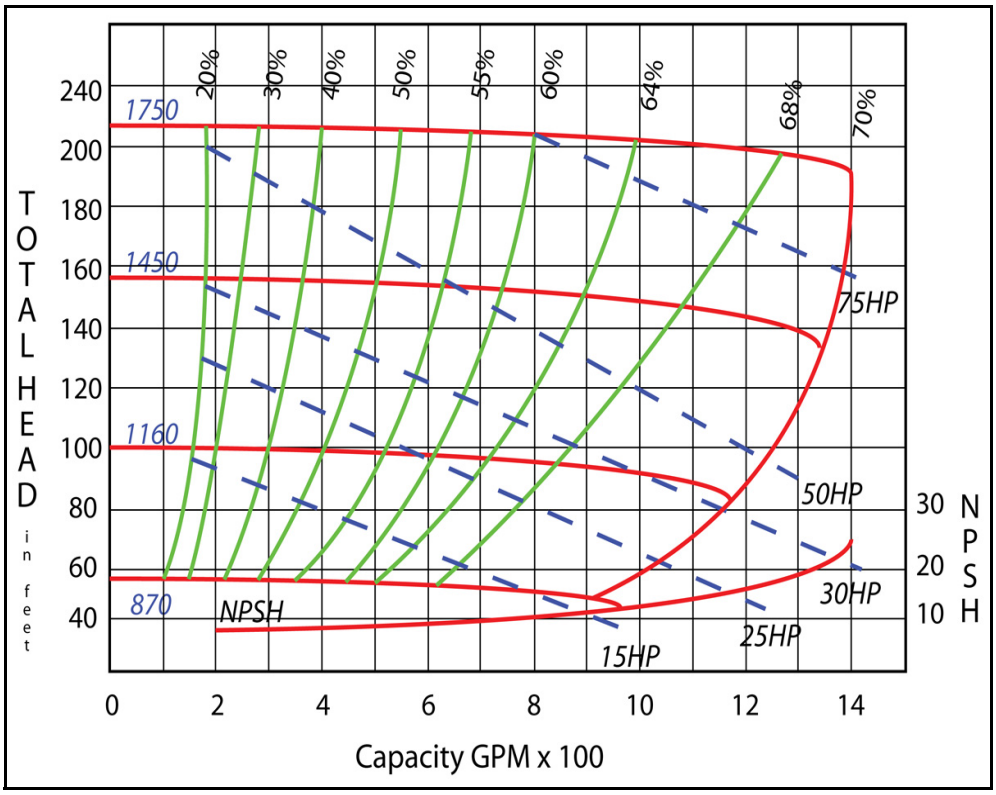

Figure 7.11: Pump performance curve. *Source: TEEX*

Pump Efficiency

Slide 39

Check efficiency periodically by measuring pump performance against manufacturer's specifications.

As head increases, pump capacity and efficiency decrease. Pump efficiency is affected by:

- high suction lift,
- worn impellers,
- clogged impellers, and
- high discharge head.

Pump Operation and Maintenance

Pump Rooms

Slide 40

Keep pump rooms clean. Keep walls, floors, and equipment painted and in good repair. An attractive work environment results in good employee morale and good public image.

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Pump Installation

Install a gate valve on the pump discharge and on the pump suction if there is a positive suction head. Install a check valve at the discharge to prevent water from flowing back through the pump when it is not running. Service pumps at storage tanks must have a low level cutoff to prevent pump damage.

Proper lubrication and packing will maintain efficient operation. Water lines for water-lubricated pumps must be operating before start-up.

Before starting a newly installed pump, assure that the pump and motor are aligned, the shaft rotates freely by hand, and the foundation is stable to prevent vibrations from straining pump casings. Check impeller rotation and motor voltage.

Pump Problems

Slide 41

Some common pump problems include the following:

- Misalignment of pump and motor
- Foreign matter in the impeller
- Air leaks in the suction
- Pump rotating backwards. A foot valve, check valve, or ratchet will prevent this. Rotating backwards can unscrew a drive shaft coupling or damage the pump or motor if the motor suddenly starts.
- Cavitation. Cavitation occurs inside the pump volute or casing. It is caused by insufficient pressure on the suction side of the pump to bring water in as fast as it leaves. The vacuum created causes water vapor bubbles to form. During pumping, the bubbles collapse, causing a mechanical shock that chips metal away from the impeller or casing.
- Water hammer. A noisy vibration caused by pressure surges when a pump stops. Automatically controlled valves reduce surges.

Pump Sanitation

Slide 42

Protect pumps from contamination. Do not lay suction lines in contaminated areas. When suction is under a vacuum, contaminants can be drawn into the pump. Therefore, maintain a positive suction head whenever possible.

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Motors

Motor Design

Slides 43-44

Most water pumps have electric motors. The most common is the squirrel cage induction motor (Figure 7.12). Synchronous motors are used where 100 hp or more is required.

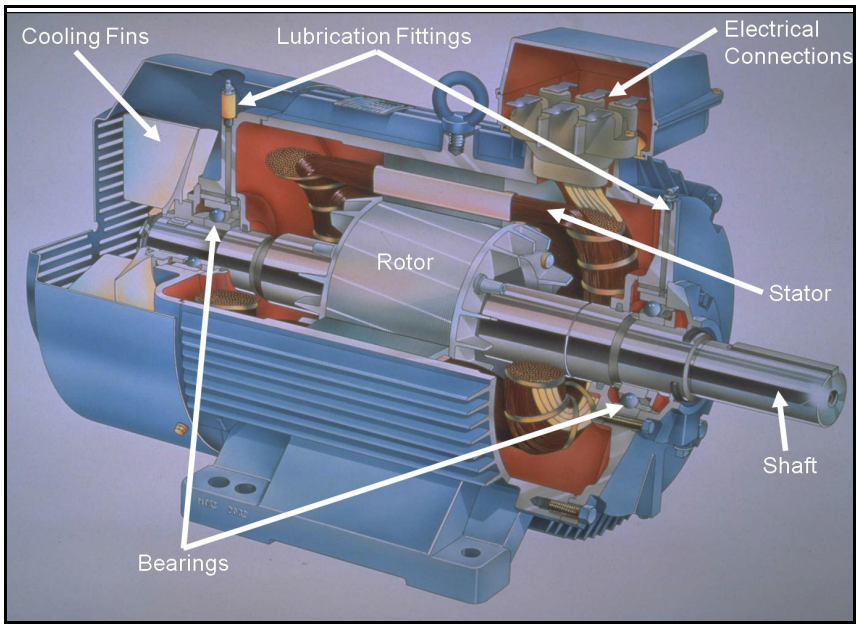

Figure 7.12: Squirrel cage induction motor. *Source: ABB, Inc.*

Motor Operation

For best efficiency, follow manufacturer's recommendations for motor maintenance. Proper ventilation prevents overheating and clean motors prevent short circuits. Assessing voltage, connections, bearings, motor ventilation, short-cycling, and overload prevention results in long service.

Keep motor controls free of dust and corrosion. An insulating mat protects operators from shock during operation or maintenance.

Summary

Slide 45

In this module, we learned about the disinfection, operation, and maintenance of a water distribution system. In the next module, we will overview safety as it pertains to the water utility industry.

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Module 7 Review Questions

1. Storage facilities equalize demand on the water supply.

   a. **true**

   b. false

2. Storage allows uniform pump rates, supplies water for firefighting, and provides time for disinfection.

   a. **true**

   b. false

3. Ground storage at a surface water treatment plant is called a **clean** well.

   a. true

   b. **false**

4. The TCEQ requires storage tanks to have covered vents, an airtight cover, **overruns,** and escape hatches.

   a. true

   b. **false**

5. If ground storage is the only storage, capacity must be 20 gallons per connection. Otherwise, total storage capacity (elevated storage included) must be **300** gallons per connection.

   a. true

   b. **false**

6. If a 30-inch diameter access opening is not provided in a storage tank, the primary roof access must not be less than 30 inches.

   a. **true**

   b. false

7. Storage must be painted, disinfected, and maintained according to **OSHA** standards.

   a. true

   b. **false**

8. No paint, coating, or wax containing lead is allowed.

   a. **true**

   b. false

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9. Coatings for contact with potable water must be approved by EPA, the National Sanitation Foundation, or the Food and Drug Administration.

   a. **true**

   b. false

10. Elevated storage is a tank, usually steel, supported aboveground on a tower.

    a. **true**

    b. false

11. Pressure from an elevated tank is maintained by the height of the water column.

    a. **true**

    b. false

12. Each foot of water column produces **0.334 psi.**

    a. true

    b. **false**

13. Water stored at least 80.85 feet above the highest service connection provides the state's minimum normal operating pressure of 35 psi.

    a. **true**

    b. false

14. A standpipe is a tank resting on the ground that is greater in height than diameter.

    a. **true**

    b. false

15. Pressure inside a hydropneumatic tank is provided by air mechanically compressed against the water surface.

    a. **true**

    b. false

16. The exterior and interior of ground, elevated, standpipe, and pressure tanks must be inspected **monthly**.

    a. true

    b. **false**

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17. Storage tank inspection results must be kept at least five years.

    a. **true**

    b. false

18. Cathodic protection is an electrochemical method of preventing corrosion of the **exterior** of metal tanks.

    a. true

    b. **false**

19. Ownership signs must include the utility name and emergency phone number at each production, treatment, or storage site.

    a. **true**

    b. false

20. Chain link fence material **must leave** a gap at the ground to trim grass.

    a. true

    b. **false**

21. The state requires stored water to have a disinfectant **demand**.

    a. true

    b. **false**

22. After construction or maintenance of a storage tank, a bacteriological sample must be taken after filling the tank.

    a. **true**

    b. false

23. If the bacteriological sample is **negative**, more samples must be taken until two consecutive samples are positive.

    a. true

    b. **false**

24. Critical safeguards of a distribution system include a chlorine residual, adequate pressure, bacteriological sampling, and cross-connection control.

    a. **true**

    b. false

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25. The TCEQ requires that distribution pressure never fall below 20 psi, even during emergencies, and normal distribution pressure must be at least 35 psi.

    a. **true**

    b. false

26. Material used in water line construction must meet **OSHA** specifications and should not affect the taste, odor, or quality of the water.

    a. true

    b. **false**

27. Plastic pipe must be NSF approved and have an ASTM pressure rating of at least 50 psi or a standard dimension ratio of **62**.

    a. true

    b. **false**

28. Select pipe on the basis of strength, **length** carrying capacity, durability, ease of installation, availability, soil conditions, and cost.

    a. true

    b. **false**

29. Prior to January 1, 2014, pipe and fittings containing more than 8.0% lead, or solders and flux containing more than 0.2% lead, are prohibited in a public water supply.

    a. **true**

    b. false

30. Isolating valves cut off sections of a system.

    a. **true**

    b. false

31. Flushing solves problems of taste, odor, red water, or bad samples.

    a. **true**

    b. false

32. The positive displacement meter is the most common design for residential use.

    a. **true**

    b. false

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33. Mains must be no closer than **10** feet, in all directions, from sewers or manholes.

    a. true

    b. **false**

34. Trenches for laying six-inch and larger pipe must be at least 18 inches wide and _____ inches wider than the pipe diameter.

    a. **12**

    b. 10

    c. 8

    d. 6

35. The top of a pipe in a trench must have at least _____ inches of cover.

    a. 30

    b. **24**

    c. 18

    d. 12

36. Do not work in a trench _____ feet or deeper unless it is protected from cave-in.

    a. 7

    b. 6

    c. **5**

    d. 4

37. Using timber, plywood, or commercial devices to support an excavation is known as _____.

    a. sloping

    b. **shoring**

    c. sheeting

    d. bracing

38. Shoring is not necessary if the trench walls are sloped to the maximum allowable _____.

    a. slant

    b. recline

    c. dispose

    d. **slope**

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39. Place spoil banks at least _____ feet from the excavation.

    a. 4

    b. 3

    c. **2**

    d. 1

40. Dose new mains with _____ mg/L or more of chlorine at least _____ hours.

    a. 100/3

    b. 25/24

    c. 500/24

    d. **a or b**

41. Do not place a main into service until a bacteriological sample is tested with _____ results.

    a. positive

    b. no

    c. **negative**

    d. doubtful

42. One sample is required for each _____ feet of completed main.

    a. 10,000

    b. 100

    c. 10

    d. **1,000**

43. Flushing reduces slime and scale buildup, reduces red water complaints, brings chlorinated water to contaminated areas, and removes _____, reducing materials from the system.

    a. **chlorine**

    b. iron

    c. calcium

    d. nitrate

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44. Closing a hydrant valve too fast can cause water _____.

    a. slammer

    b. boomer

    c. mallet

    d. **hammer**

45. _____ is a buildup of oxidized iron, calcium carbonate, or other chemicals in mains.

    a. tuberculosis

    b. **tuberculation**

    c. turbidity

    d. slime

46. Factors that make water more corrosive are low pH, dissolved oxygen, and _____.

    a. **free chlorine**

    b. combined chlorine

    c. free iron

    d. combined minerals

47. Repairing a leak under some pressure has an advantage of _____.

    a. interrupting service

    b. **reducing contamination risk**

    c. increasing air in the main

    d. ensuring the repair fails under service

48. A cross connection is a physical connection between a public water supply, and 1) another supply of unknown or questionable quality, 2) any source that may contain contamination, 3) any water _____.

    a. safe to drink

    b. treated to potable quality

    c. treated to a greater degree

    d. **treated to a lesser degree**

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49. The air gap is the only cross-connection control method approved by the TCEQ for protection against _____.

    a. water theft

    b. air leaks

    c. hose sprayers

    d. **sewage contamination**

50. When storms are expected, the water utility should alert personnel, check communications, fill gasoline tanks, check emergency equipment, fill storage tanks, and _____.

    a. reduce stock of repair clamps and calcium hypochlorite

    b. write emergency procedures

    c. **isolate elevated storage**

    d. insulate elevated storage

51. The most common pump in the water utility field is the _____ pump.

    a. deep-well turbine

    b. **centrifugal**

    c. priming

    d. displacement

52. Water is forced out of the volute of a centrifugal pump by _____ force.

    a. velocity

    b. suction

    c. **centrifugal**

    d. turbine

53. Three types of pump curve are head capacity curve, efficiency curve, and _____ curve.

    a. gpm

    b. psi

    c. voltage

    d. **horsepower**

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54. As the force a pump works against increases, the capacity and efficiency _____.

    a. increase

    b. **decrease**

    c. equalize

    d. stabilize

55. Install a check valve in a pump discharge line to prevent water from flowing _____ during shutdown.

    a. **back through the pump**

    b. through a cross connection

    c. uphill

    d. from supply

56. Common pump problems include _____ and water hammer.

    a. proper alignment of pump and motor

    b. air-tight suction

    c. **cavitation**

    d. unclogged impeller

57. The most common motor is the _____ motor.

    a. squirrel cage reduction

    b. synchronous

    c. squirrel cage deduction

    d. **squirrel cage induction**

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Module 7 Presentation Slides

Basic Water Operations

Module 7
Distribution

Terminal Objective

Upon successful completion of this module, the participant will be able to describe the common methods of water delivery to the public following water treatment.

Enabling Objectives

- Discuss the different types of storage.
- List the major components of the distribution system.
- Explain the different aspects of pump usage for distribution.
- Discuss the use of motors in distribution system pumps.

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Storage Reservoirs

- Facilities equalize demand on water supply
- Low demand = storage filling
- High demand = storage depletion
- Allows uniform pumping rates
- Supplies water for firefighting
- Provides time for disinfection

Types of Storage: Ground Storage

- Called a clear well
- Meet TCEQ requirements
- Corrosion-resistant screens
- <1/16" gap at overflow cover
- Entry port rim meets requirements
- Capacity is 200 gallons per connection

Types of Storage: Ground Storage

- **Primary roof access not <30 inches**
- **Proper access provided when during maintenance**
- **Painted, disinfected, maintained to AWWA standards**
- **No lead products allowed**
- **Coatings must be approved**

Source: TEEX

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Types of Storage: Elevated Storage

Source: TEEX

- Pressure maintained by water column height
- 1 ft. of water column = 0.433 psi
- Required for systems with >2,500 connections
- Must meet ground storage criteria
- Minimum psi of 35/20
- 80.85 ft. above highest connection

Types of Storage: Standpipe Storage

- Resting on the ground
- Greater in height than diameter
- If >80.85 feet tall, considered elevated storage
- Usually built on elevated ground
- Must meet elevated storage criteria

Source: TEEX

Types of Storage: Pressure Tanks

Source: TEEX

- Hydropneumatic tanks
- Cylindrical
- Horizontal to the ground
- Air mechanically compressed against water surface

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Storage Maintenance

- Annual inspections
  - Interior/exterior of tanks
  - Meet AWWA standards
- Corrosion protection
- Ownership signs
- Grounds keeping

Sanitary Protection

- Stored water must have disinfectant residual
- Location of underground tanks
- Cracks/leaks must be repaired
- Prevent other contaminants from entering
- Must be disinfected after construction/maintenance

Distribution Systems

- Mains, service lines, meters
- Valves, hydrants, pump stations
- Must meet standards
- Critical safeguards
- >20 psi pressure required by TCEQ
- 35+ psi for normal distribution pressure

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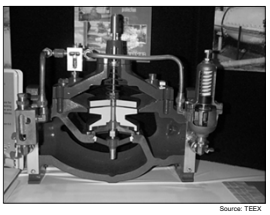
Distribution System Components

- Pipe Materials
  - Ductile iron, cast iron, steel, concrete
  - Plastic pipe is most common
- Pipe Joints
  - Select pipe based on several factors
  - Maximum lead content – fittings, solders, flux

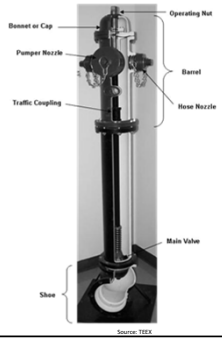
Distribution System Components

- **Valves**
  - Isolating valves cut off system sections
  - Gate valve most common
  - Controlling valves regulate pressure, flow rate, direction
  - Globe, diaphragm, rotary valves



Source: TEEX

Distribution System Components



Source: TEEX

- **Fire Hydrants**
  - Firefighting, flushing
  - Assists in solving problems
  - Bleed air from mains after construction

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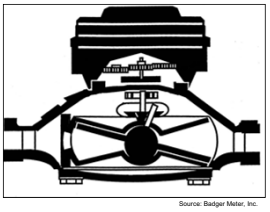
Distribution System Components

- **Water Meters**
  - Measure flow for plant, distribution, customer
  - Propeller, compound, magnetic meters
  - Positive displacement meter for residential use
  - Utilities' income

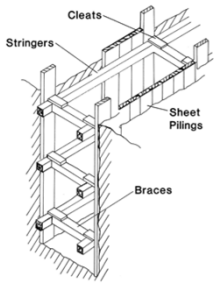


Source: Badger Meter, Inc.

Pipe Installation

- Main Installation
  - Separation distances
  - TCEQ separation distance requirements
  - Trenches
  - Cover material
  - Texas, 30–60 in. rule
  - 24 in. cover

Trench Safety



Source: TEEX

- >5 ft. deep, protect from cave-in
- Shoring – support for an excavation
- Sloping – degree slope to overcome cave-in
- Spoil bank placement, 2 ft. from excavation

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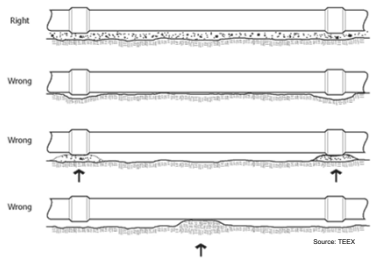
Pipe Bedding

- Minimum 4 in. or 1/4 of pipe diameter
- Backfill trench after bedded
- Bed with tamped sand or gravel



Pipe Bracing

- Used for changes in line direction
- Bracing placed at the bend OR
- Blocked against internal thrust

Sanitation

- Trenches should be clean/dry
- Ditch water should not enter pipe
- Maintain sanitary conditions
  - Swab pipe with hypochlorite solution
  - Never leave installed pipe with open end

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Disinfection AWWA Standard C651-92

- Three methods chlorination for mains
  - Tablet
  - Continuous
  - "Slug"
- Table 7.1 provides details
- After disinfection, flush lines
- Take Bac-T sample

Maintenance of Distribution System

- Flushing
  - Flush dead-end mains once/month
  - Reduces slime, scale buildup, red water
  - Brings fresh chlorinated water to contaminated areas
  - Reduces chlorine-demanding materials
- Flush carefully to prevent damage

Maintenance of Distribution System

- Scale (Tuberculation)
  - Buildup of oxidized iron, calcium carbonate
  - Removal methods
- Corrosion
  - Dissolving of metal that damages tanks
  - Affects water quality

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Corrosion

- Factors that cause corrosion
  - Low pH
  - Dissolved O_2 and CO_2
  - Dissolved salts
  - Free chlorine
  - Low hardness

Corrosion

- Factors that cause corrosion (cont.)
  - High velocity
  - High temperature
  - Alkalinity
  - Fate-reducing bacteria

Corrosion Control

- Pipe with protective linings/coatings
- Anodes on storage tanks
- Eliminate different metals in system
- Treat water with chemicals
- Use dielectric unions to separate metals

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Main Repairs

- Main breaks are challenging to any utility
  - Need proper equipment and supplies
- When a leak is found
  - Excavate below pipe on both sides
  - Dig one side deeper to form sump
  - Keep pooled ditch water out

Main Repairs

- Repairing mains under pressure
  - If possible, repair the leak "hot"
  - This prevents interrupted service
  - Reduces risk of contamination
  - Reduces air in the main
  - Ensures the repair holds under service

Cross-Connection Control

- What is a cross connection?
- Examples of a cross connection
- TCEQ requirements
  - Air gap method
  - Backflow prevention device

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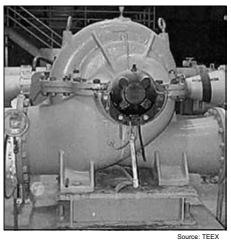
Emergency Preparedness

- Have repair manuals readily available
- Have spare parts on hand
- Alert personnel and prepare emergency equipment
- Fill storage tanks, isolate elevated storage
- Restock clamps and calcium hypochlorite
- Review emergency procedures

Types of Pumps

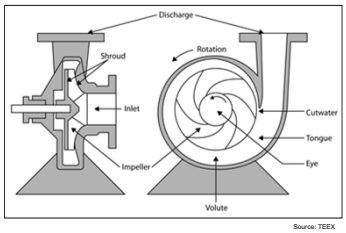


Source: TEEX

- **Centrifugal**
  - Most common
  - Should be designed for specific job
  - Primed by filling volute with water

Centrifugal Pumps

- **Motor causes impeller to spin**
- **Water is thrown out by centrifugal force**
- **Water supplied by suction lift, suction head**



Source: TEEX

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Deep Well Turbine

Source: American Turbine

- Used in water wells
- Vertical impellers move water
- Either oil or water lubricated
- Line must be on before starting

Pump Selection Factors

- Amount of water to be pumped
- Force (head)
- Material to be pumped
- Cost
- Availability
- Pump efficiency

Pump Selection

- Pumping rate
  - Gallons/minute or million gallons/day
- Head
  - Force that the pump works against
  - Static = no flow or pumping
  - Dynamic = there is flow or pumping

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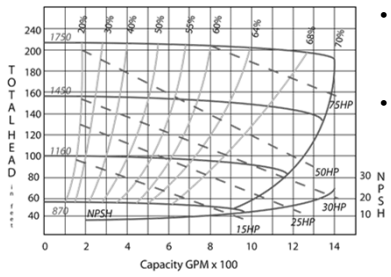
Terminology

- Suction lift
- Suction head
- Discharge head
- Total static head
- Friction head
- Total dynamic head

Pump Curves



- **Assists in selection of pump**
- **Three types of pump curves**
  - Head capacity
  - Efficiency
  - Horsepower

Source: TEEX

Pump Efficiency

- Check periodically
- As head increases, efficiency decreases
- Acting forces on efficiency
  - High suction lift
  - Worn/clogged impellers
  - High discharge head

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Pump Operation and Maintenance

- Pump Room
  - Keep clean, in good repair
- Valve installation
  - Install gate valve on pump discharge
  - Install check valve at discharge

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Pump Problems

- Misalignment of pump and motor
- Foreign matter in the impeller
- Air leak in the suction
- Pump rotating backwards
- Cavitation
- Water hammer

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Pump Sanitation

- Protect pumps from contamination
- Keep suction lines out of contaminated areas
- Vacuum can draw in contaminants
- Maintain positive suction head, if possible

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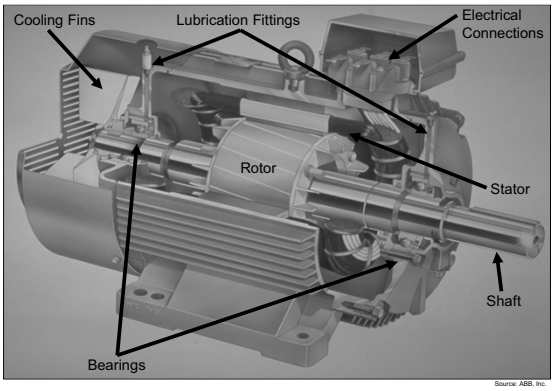
Electric Motors

- Squirrel cage induction most common
- Motor operation
  - Follow manufacturer's recommendations
  - Proper ventilation
  - Preventive measure to ensure long service
  - Insulation for shock protection



Module 7

Review Questions

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End of Module 7

Next Module:
Safety

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Module 8

Safety

Terminal Objective

Upon the successful completion of this module, the participant will be able to explain proper safety procedures for water employees.

Enabling Objectives

1. Explain how state and federal laws protect workers.
2. Explain the needed elements for an effective safety program.
3. Describe the main hazards particular to water utility operators.
4. Review chemical safety for water utility employees.
5. Review traffic control for water utility employees.

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Instructional Guidance

Time

1 hour, 20 minutes

Materials/Equipment

1. Participant manual
2. Laptop with presentation slides for module 8
3. Internet connectivity
4. Video/data projector
5. Screen or monitor

Instructor Preparation

Prepare projector and position first presentation slide.

Application of Participants' Knowledge/Skills

Have participant complete the review questions at the end of the module.

Evaluation of Participants

Go over the review questions at the end of the module, answering any questions the participant may still have.

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Introduction

Slides 1-5

Working in the water and wastewater industry is dangerous! Employees are exposed to chemicals, high voltage, traffic, excavations, deep water, animal bites, confined spaces, and more. However, with the proper attitude and training, accidents can be avoided because they are caused and do not just happen.

We begin this module with a synopsis of hazards applicable to the water utility industry. Various state and federal laws, in addition to utility safety programs, are designed to protect water utility employees.

Federal and State Laws

Slide 6

The federal law regulating workplace safety is the Occupational Safety and Health Act (OSHA). The law applies only to industrial, manufacturing, and private business employers. Although state, municipal, public school, and most federal employers are not required to follow OSHA regulations, they have a moral obligation to provide a safe workplace. Employers not under OSHA may utilize the federal regulations as guidelines for their safety programs.

The "Right-to-Know" Law is a federal law that was adopted by the state as the Texas Hazard Communication Act. This act requires employers not bound by OSHA to provide information about hazardous chemicals in the workplace. This law applies to all state, county, and municipal employees.

Slide 7

One requirement of the Texas Hazard Communication Act is employee access to a Safety Data Sheet (SDS). The SDS is hazardous product information supplied by the manufacturer. An SDS states product hazards and precautions.

Safety Programs

A safety program must start with support from the top official, then extend to all employees. Everyone must participate or the program will fail.

Slide 8

Elements of a safety program include:

- a written policy,
- supportive administration,
- trained employees,

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- safety inspections,
- accident review, and
- recordkeeping.

Information for setting up safety programs is available from the Texas Department of State Health Services and the Texas Municipal League. Libraries also have information regarding safety programs.

Particular Water Utility Hazards

Slide 9

Four hazards especially dangerous to water utility operators are:

- confined space entry,
- excavation and trenching,
- chemical handling, and
- traffic.

Confined Space Entry

Confined Space Definition

Slide 10

According to OSHA 29 CFR Part 1910.146, three criteria classify a confined space.

> A confined space is 1) large enough and so configured that an employee may enter and do work; 2) has limited or restricted means of entry or exit; and 3) is not designed for continuous occupancy.

Examples of confined spaces are vaults, pits, water tanks, storage tanks, pump rooms, and trenches.

Hazard Categories

The hazards to water utility employees are as follows:

- Hazardous atmospheres—such as a lack of oxygen
- Engulfment—while working in a tank that begins to fill
- Chemical—exposure to hazardous chemicals
- Mechanical—exposure to moving components of machinery
- Electrical—exposure to energized electrical equipment

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- Biological—exposure to human waste
- Radiological—exposure to radioactive material

The number one cause of death in a confined space is lack of oxygen.

Gases

Slides 11-12

Combustible gases include methane, hydrogen sulfide, and carbon monoxide. Hydrogen sulfide and carbon monoxide are monitored with a toxic sensor because they are toxic long before they are combustible.

Do not rely on sense of smell or sight to identify any gas. Cockroaches are not gas detectors! They can adapt to conditions that would kill a human. Use a direct reading instrument to check first for oxygen content, then combustibles, then toxins, in that order.

Refer to Table 8.1 for a listing of gases and their characteristics.

Table 8.1: Gases

Gas and Symbol	Properties	Effect on Humans	Most Common Sources	Method of Testing
Oxygen (in air) O_2	Colorless, odorless, tasteless, nonpoisonous. Supports combustion.	Normal air contains 20.9% O_2. Humans tolerate down to 12%. Less than 5–7% likely to be fatal.	Poor ventilation or chemical consumption of available O_2.	Oxygen deficiency indicator.
Carbon Monoxide CO	Colorless, odorless, nonirritating, tasteless. Flammable, explosive.	0.2–0.25% causes unconsciousness in 30 minutes. Blood will absorb CO more readily, causing oxygen starvation.	Product of incomplete combustion.	CO ampoules.
Methane CH_4	Colorless, odorless, tasteless, nonpoisonous. Flammable, explosive.	Deprives tissues of oxygen, an apshyxiant.	Natural gas, marsh gas, fuel gas, and sewer gas.	Combustion gas indicator. Oxygen deficiency indicator.

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Table 8.1: Gases (Continued)

Gas and Symbol	Properties	Effect on Humans	Most Common Sources	Method of Testing
Hydrogen Sulfide H_2S	Colorless, poisonous. Rotten egg odor in small concentrations, odor not evident at high concentrations. Flammable, explosive.	Death in a few minutes at 0.2%. Paralyzes respiratory center.	Petroleum fumes, blasting fumes, sewer gas.	H_2S analyzer. H_2S ampoules.
Carbon Dioxide CO_2	Colorless, nonflammable, odorless. Not usually present in dangerous amounts unless oxygen is already deficient.	10% is fatal after a few minutes. Acts on nerves of respiration.	Issues from carbonaceous rock layers. Sewer gas.	Oxygen deficiency indicator.
Chlorine Cl_2	Greenish-yellow gas, amber in liquid state. Penetrating odor. Highly corrosive in the presence of moisture.	Highly irritating to eyes and mucous membranes. Causes violent coughing. Heavy exposure is fatal.	Leaking connections, overdosage in treatment.	Chlorine detector. Ammonia vapor gives off white fumes. Oxygen deficiency indicator.

Confined Space Program

Slide 13

The employer must identify all confined spaces and determine their hazards. After evaluation, the spaces are designated "permit required" or "non-permit required." The employer must train operators to work safely in confined spaces and must provide them with safety equipment.

A non-permit confined space is defined as a confined space that does not contain or, with respect to atmospheric hazards, have the potential to contain any hazard capable of causing death or serious physical harm. If an employer can document that forced air ventilation will eliminate all atmospheric hazards the space may be classified as non-permit required.

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Slide 14

"Permit-required" confined space (permit space) means a confined space that has one or more of the following:

- Contains or has potential to contain a hazardous atmosphere
- Contains a material that has potential for engulfing an entrant
- Has an internal configuration such that an entrant could be trapped/asphyxiated by inwardly converging walls or by a floor that slopes downward and tapers to a smaller cross section
- Contains any other recognized serious safety/health hazard

Slide 15

When entering a "permit required" space, personnel must wear a harness and be attached to a retrieval line. OSHA requires an anti-fall line if a portable ladder or stairs are not used. When a vertical entry of five feet or more is made, the retrieval line must be attached to a mechanical retrieval device. This allows a non-entry rescue.

Rescuers must be trained in confined space rescue and be available before an entry occurs. They do not have to be on site, but must be able to respond in appropriate time.

Excavation and Trenching

Slide 16

For years, Texas had more deaths due to cave-ins than any other state. The legislature passed laws requiring private employers such as contractors to follow OSHA excavation and trenching rules (OSHA 29 CFR Part 1926.650-653). These regulations do not apply to state, county, or municipal employers.

Cave-In Protection

Slide 17

When an excavation is five feet or deeper, a means of cave-in protection is required. This can be shoring, shielding, or sloping. Shoring, shielding, and sloping protect workers from collapsing trench walls.

Shoring uses timbers or hydraulic wedges and sheeting (Figure 8.1 and Figure 8.2).

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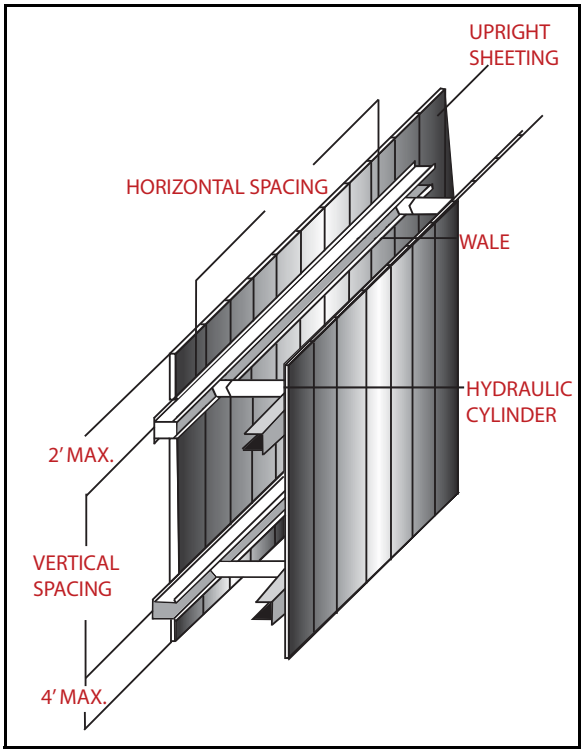

Figure 8.1: Aluminum hydraulic shoring. *Source: TEEX.*

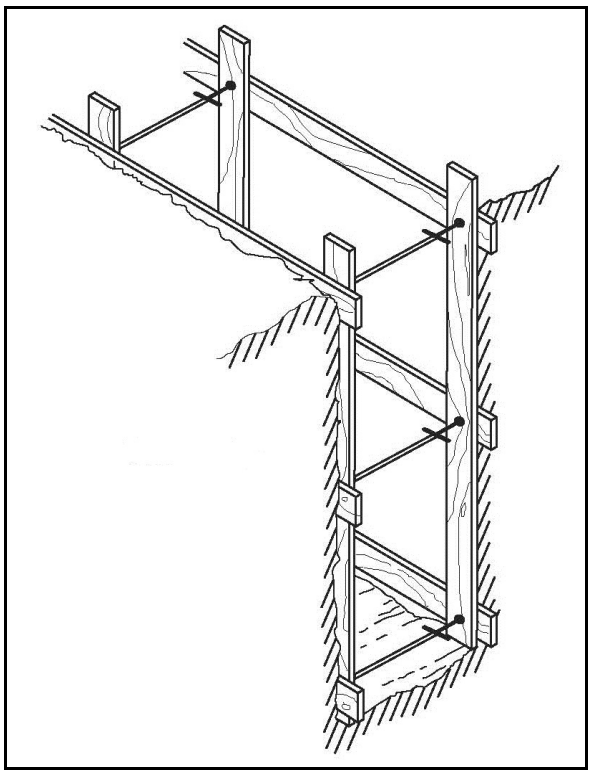

Figure 8.2: Trench shoring in hard ground. *Source: TEEX.*

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Slide 17

Shields or trench boxes are movable, and cannot prevent a cave-in. Therefore, workers must stay within the shield or box (Figure 8.3).

Figure 8.3: Trench box. *Source: TEEX.*

Slide 17

Benching is a type of sloping done by cutting stair steps in the trench wall while maintaining the maximum allowable slope (Figure 8.4).

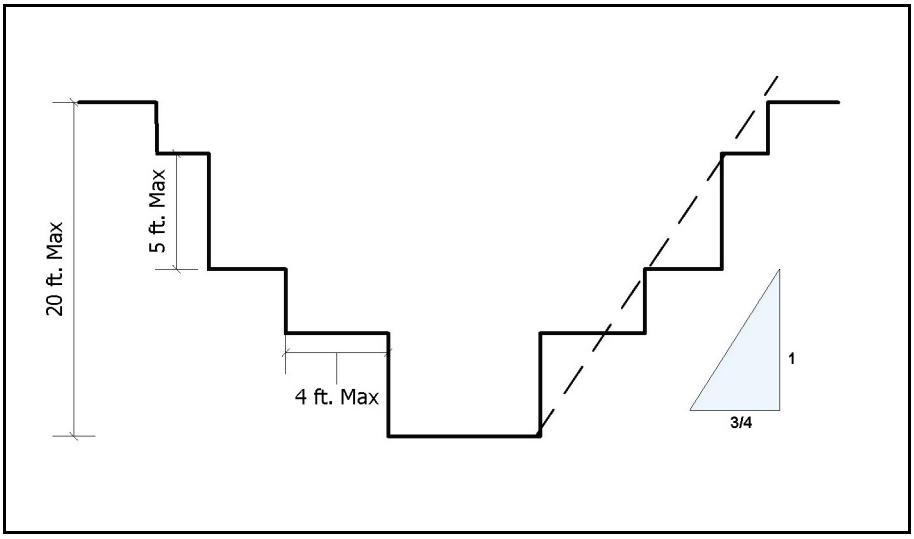

Figure 8.4: Benching. *Source: TEEX.*

Sloping cuts trench walls to the angle that overcomes collapsing pressure. Soil type determines the **maximum allowable slope** or angle of repose. OSHA classifies soil into four categories: stable rock, and types A, B, or C. If the soil is previously disturbed, it is type C (Table 8.2).

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Table 8.2: Classification of Soil Types and Angles for Sloping

Soil Types	Maximum Allowable Slope	Horizontal Run to Vertical Rise
Stable rock	90°	0
Type A	53°	¾:1
Type B	45°	1:1
Type C	34°	1½:1

The maximum allowable slope is utilized when sloping the trench walls to prevent the trench from caving in. If in doubt about the soil type always consider it a Type C soil, requiring a 34° angle from horizontal. This is done by using the run to rise listed in the chart. For a Type C soil this is 1½ ft. run to 1 ft. rise. The backhoe operator would dig 1½ ft. horizontally while going up only 1 ft. Continuing to excavate in this manner would ensure a 34° slope. It is important to excavate both sides of the trench in this manner.

Trench Exits and Spoil

If the excavation is four feet or deeper, a means of exit must be provided. Ramps or ladders are acceptable. If a ladder is used, it must extend at least three feet above the top of the excavation, be secured, and be within 25 feet laterally of anyone in the excavation.

Excavation spoil must be kept at least two feet from the excavation edge. Spoil is the material excavated from an excavation.

Chemical Safety

Slide 18

Water utility employees may use dangerous chemicals everyday and have a right to product information under the Texas Hazard Communication Act (Right to Know law). The components of the act are as follows:

- A written program
- Posted “Notice to Employees”
- Personal protection equipment
- Hazardous material training
- Safety Data Sheets (SDS)
- Employee rights protection
- State notification of chemical injuries

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Traffic Control

Slide 19

Improper warning signs and barricades cause most work area accidents on streets and highways. Traffic control must not confuse motorists. Workers should be trained from the Texas Manual on Uniform Traffic Control Devices (TMUTCD), Texas Department of Transportation, Austin (Figure 8.5).

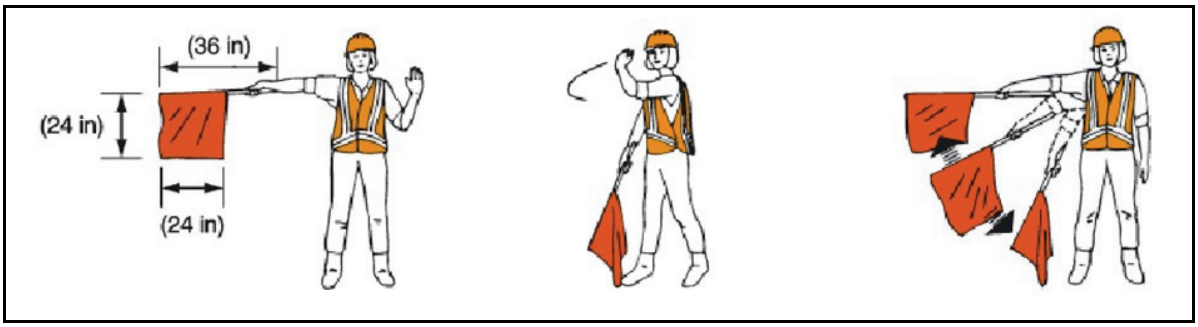

Figure 8.5: Traffic control flaggers. *Source: TxDOT*.

Summary

Slide 20

Safety is a concern for employees in any industry. It is important to understand policies and procedures and their role in the water utility industry because of their importance to the well-being of water utility employees.

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Module 8 Review Questions

1. Nine out of ten accidents result from unsafe acts of the person injured or someone else.
   a. **true**
   b. false

2. The federal law regulating workplace safety is the Occupational Safety and Health Act.
   a. **true**
   b. false

3. The Texas Hazard Communication Act is known as the "Right to **Work**" law.
   a. true
   b. **false**

4. A safety program must start from the bottom, and then extend to the **top official**.
   a. true
   b. **false**

5. Everyone must participate in a safety program or it will fail.
   a. **true**
   b. false

6. A confined space is 1) large enough to enter and do work; 2) has limited or restricted entry or exit; and 3) is not designed for continuous occupancy.
   a. **true**
   b. false

7. The number one cause of death in a confined space is lack of oxygen.
   a. **true**
   b. false

8. Combustible gases include methane, hydrogen sulfide, and carbon **dioxide**.
   a. true
   b. **false**

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9. Cockroaches can adapt to conditions that would kill a human.

   a. **true**

   b. false

10. After evaluation, confined spaces are designated "entry allowed" or **"entry denied."**

    a. true

    b. **false**

11. When entering a "permit required" space, personnel must wear a harness and be attached to a _____ line.

    a. life

    b. **retrieval**

    c. tow

    d. drag

12. OSHA requires an anti-fall line if a portable ladder or _____ are not used.

    a. shoring

    b. trench boxes

    c. **stairs**

    d. ropes

13. When a vertical entry of _____ feet or more is made, the retrieval line must be attached to a mechanical retrieval device.

    a. **5**

    b. 4

    c. 3

    d. 50

14. Private employers, such as contractors, must follow _____ excavation and trenching rules.

    a. **OSHA**

    b. AWWA

    c. TCEQ

    d. EPA

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15. When an excavation is _____ feet or deeper, a means of cave-in protection is required.

    a. 2

    b. 3

    c. 4

    d. **5**

16. Cave-in protection includes shoring, shielding, and _____.

    a. ventilation

    b. personal protective equipment

    c. **sloping**

    d. flagging

17. Shoring uses timbers or hydraulic wedges and _____.

    a. **sheeting**

    b. nails

    c. steel cables

    d. ropes

18. Benching is a type of sloping done by cutting stair steps in the trench wall while maintaining the maximum allowable _____.

    a. spoil

    b. slip

    c. slide

    d. **slope**

19. Sloping cuts trench walls to the angle that overcomes collapsing _____.

    a. soil

    b. spoil

    c. **pressure**

    d. tension

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20. OSHA classifies soil into four categories: _____ rock, class A, class B, and class C.

    a. hard

    b. **stable**

    c. soft

    d. sharp

21. If the soil is previously disturbed, it is _____.

    a. stable rock

    b. class A

    c. class B

    d. **class C**

22. A maximum allowable slope of 45° and a run to rise of 1:1 is for soil type _____.

    a. stable rock

    b. class A

    c. **class B**

    d. class C

23. If the excavation is _____ feet or deeper, a means of exit must be provided.

    a. **4**

    b. 3.5

    c. 3

    d. 2.5

24. If a ladder is used, it must extend at least _____ feet above the edge of the excavation and be within _____ feet laterally of anyone in the excavation.

    a. 3/30

    b. 2.5/25

    c. 2/20

    d. **3/23**

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25. Excavation spoil must be kept at least _____ feet from the excavation.

    a. **2**

    b. 3

    c. 4

    d. 5

26. Water utility employees have a right to product information under the _____.

    a. Texas Right to Work Act

    b. Texas Hazardous Material Act

    c. **Texas Hazard Communication Act**

    d. Texas Hazardous Product Act

27. One of the components of the Texas Hazard Communication Act is employee access to _____.

    a. DSS

    b. SSD

    c. **SDS**

    d. DDS

28. To prevent work area accidents, workers should be trained from the *Texas Manual on Uniform Traffic Control Devices*, _____, Austin.

    a. Texas Department of Streets and Highways

    b. Texas Highway Department

    c. **Texas Department of Transportation**

    d. Texas Department of Public Safety

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Module 8 Presentation Slides

Basic Water Operations

Module 8
Safety

Terminal Objective

Upon successful completion of this module, the participant will be able to discuss proper safety procedures for water employees.

Enabling Objectives

- Explain how state and federal laws protect workers.
- Discuss the needed elements for an effective safety program.
- Describe the main hazards particular to water utility operators.

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Enabling Objectives (cont.)

- Review chemical safety for water utility employees.
- Review traffic control for water utility employees.

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Hazards of Our Trade

- Chemicals, high voltage, traffic, excavations
- Deep water
- Animal bites
- Confined spaces
- Machinery
- Hand tools

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Federal and State Laws

- Occupational Safety and Health Act (OSHA)
- Applies to industrial, manufacturing, private business
- State, municipal, public school, federal employees exempt

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Texas Hazard Communication Act

- "Right-to-Know" Law
  - Provide info on hazardous chemicals in workplace
  - Applies to state, county, municipal employees
  - Provides access to SDS

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Safety Programs

- Elements of a safety program
  - Written policy
  - Supportive administration
  - Trained employees
  - Safety inspections
  - Accident reviews and recordkeeping

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Water Utility Hazards

- Confined space entry
- Excavation and trenching
- Chemical handling
- Traffic

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Confined Space Entry

- What is a confined space?
- Types of hazards
  - Hazardous atmospheres
  - Engulfment
  - Chemical, mechanical, electrical
  - Biological or radiological

Confined Space Entry

- Gases
  - Lack of oxygen is #1 cause of death
  - Combustible gases
  - Toxic gases
- Do not rely on your sense of smell!
- Use direct reading instruments

Gases

Gas and Symbol§	Properties§	Effect on Humans§	Most Common Sources§	Method of Testing§
Oxygen (in air) O_2§	Colorless, odorless, tasteless, nonpoisonous. Supports combustion.§	Normal air contains 20.9% O_2. Humans tolerate down to 12%. Less than 5–7% likely to be fatal.§	Poor ventilation or chemical consumption of available O_2.§	Oxygen deficiency indicator.§
Carbon Monoxide CO§	Colorless, odorless, nonirritating, tasteless. Flammable, explosive.§	0.2–0.25% causes unconsciousness in 30 minutes. Blood will absorb CO more readily, causing oxygen starvation.§	Product of incomplete combustion.§	CO ampoules.§
Methane CH_4§	Colorless, odorless, tasteless, nonpoisonous. Flammable, explosive.§	Deprives tissues of oxygen, an asphyxiant.§	Natural gas, marsh gas, fuel gas, and sewer gas.§	Combustion gas indicator. Oxygen deficiency indicator.§

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Confined Space Program

- Employer must identify confined spaces
- Must determine the hazards associated
- Designate "permit required" or not
- Train operators in safe operating procedures
- Provide safety equipment

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Permit Required Confined Space

- Contains hazardous atmosphere
- Potential for engulfment
- Difficult internal configuration
- Potential for entrapment/asphyxiation
- Contains any other safety/health hazard

©2017 WWW001 14

Confined Space Program

- "Permit required" space indicates
  - Need for a harness and retrieval line
  - May require anti-fall line (OSHA)
  - Special requirements for vertical entry
- Rescuers must be trained AND available

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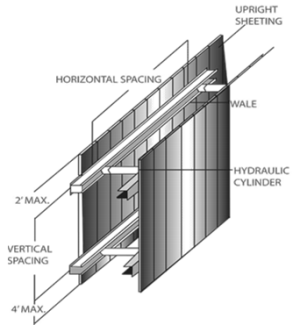
Excavation and Trenching

- OSHA requirement for 5 ft. or deeper
- OSHA 29 CFR Part 1926.650-653



Source: TEEX

Water Utility Hazards

Source: TEEX

- **Cave-in protection**
  - Shoring
  - Shields/trench boxes
  - Benching
  - Sloping
- **Trench exits and spoils**

Chemical Safety

- Employees have right to know chemical information
- PPE
- Hazardous material training
- Safety Data Sheets
- Employee protection rights
- State notification of chemical injuries

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Traffic Control

- Improper signs/barricades cause accidents
- Traffic control should not confuse drivers
- Workers should be trained from TMUTCD

Source: TXDOT TMUTCD

Module 8

Review Questions

End of Module 8

Next Module: Calculations

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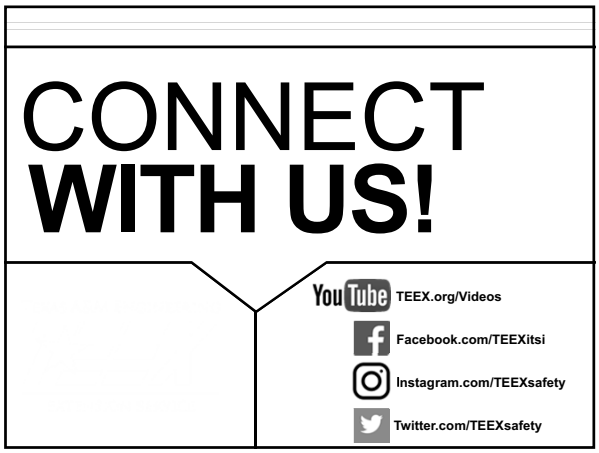

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Module 9

Calculations

Terminal Objective

Upon the successful completion of this module, the participant will be able to calculate problems related to basic water works operations.

Enabling Objectives

1. Calculate area of squares, rectangles, and circles.
2. Calculate volume in cubic feet and gallons of rectangular and cylindrical tanks.
3. Solve problems requiring the use of conversion factors.
4. Solve problems involving chemical dosage.
5. Solve problems of detention time in days, hours, and minutes.

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Instructional Guidance

Time

1 hour, 50 minutes

Materials/Equipment

1. Participant manual
2. Laptop with presentation slides for module 9
3. Internet connectivity
4. Video/data projector
5. Screen or monitor

Instructor Preparation

Prepare projector and position first presentation slide.

Application of Participants' Knowledge/Skills

Allow participants time to solve the problems presented in the PM following each type of calculation.

Evaluation of Participants

Participant activities following each type of equation will indicate to the instructor if the participant is understanding the calculations.

Discuss the correct answers and answer any questions presented by the participants. When all questions have been answered, proceed to administration of the course final exam.

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Introduction

Slides 1-4

An an employee of a water/wastewater utility, you can expect to rely on mathematical equations to solve basic water/wastewater operations problems. In this module, we will solve various problems related to the industry using multiple mathematical formulas.

> ***Instructor Note***
>
> *Review this module's objectives with participants so that they are aware of what they will be learning during this lesson.*

Area

Area of a Rectangle or Square

Slides 5-6

Formula: *Area = Length × Width*

Look at the rectangle (Figure 9.1) below.

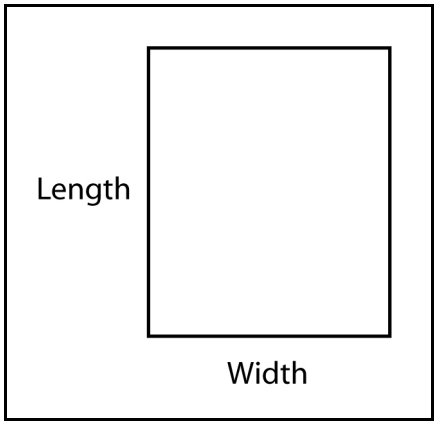

Figure 9.1: Rectangle.
Source: TEEX.

The length is 6 feet and the width is 5 feet.

Total surface area is $6 \times 5 = 30$ ft^2.

The little "2" after "ft" is a symbol for square units. It means there are two dimensions in the formula for area of a rectangle or square. Area is usually expressed in inches, feet, yards, or miles, but may be expressed in other units.

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Area of a Circle

Slide 7

Formula*: A = πR^2*

(3.14 × Radius × Radius)

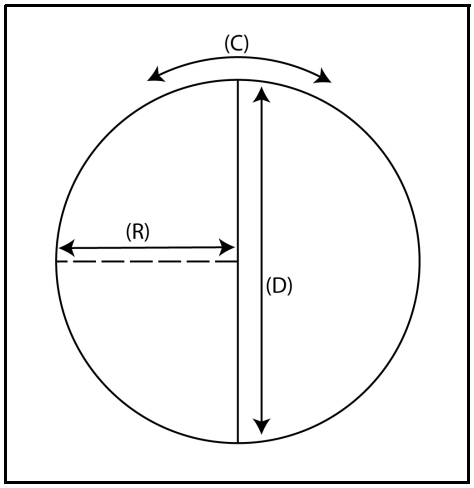

Figure 9.2: Radius of a circle.
Source: TEEX.

π (pi) is the 16th letter of the Greek alphabet and represents the number 3.14, which is the ratio of the circumference to the diameter of a circle. The circumference of a circle is 3.14 times the diameter. The circumference of a circle divided by its diameter is 3.14 (π).

Circumference (C) is the distance around a circle. Diameter (D) is the distance through the center of a circle. Radius is half the diameter of a circle (Figure 9.2).

Area is usually expressed in square units.

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Activity 9.1: Area Calculations

> ***Instructor Note***
>
> *Allow time for the participants to calculate the answers to the following questions. Be sure to answer any questions participants may have.*

Slide 8

1. What is the surface area of the bottom of a rectangular storage tank 10 feet long and five feet wide?

$$L \times W = Area\ ft^2$$

$$10 \times 5 = 50\ ft^2$$

Slide 9

2. How many square feet is the roof of a chlorinator room eight feet square?

$$L \times W = Area\ ft^2$$

$$8 \times 8 = 64\ ft^2$$

Slide 10

3. If a trench is 50 feet long and six feet wide, how many square feet will the bottom cover?

$$L \times W = Area\ ft^2$$

$$50 \times 6 = 300\ ft^2$$

Slide 11

4. What is the surface area of the bottom of a circular storage tank 20 feet in diameter?

$$\pi \times R^2 = Area\ ft^2$$

$$3.14 \times 10 \times 10 = 314\ ft^2$$

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Slide 12

5. What is the surface area of a 35-foot diameter circular roof covering a service center?

$$\pi \times R^2 = Area\ ft^2$$

$$3.14 \times 17.5 \times 17.5 = 961.6\ ft^2$$

Slide 13

6. How many square inches and square feet is the end section of a 6-inch pipe?

$$\pi \times R^2 = Area\ in^2$$

$$3.14 \times 3 \times 3 = 28.26\ in^2$$

$$\frac{in^2}{in^2/ft^2} = ft^2$$

$$\frac{28.26}{144} = 0.196\ ft^2$$

Slide 14

7. How many square feet is the end section of an 18-inch pipe?

$$\pi \times R^2 = Area\ ft^2$$

$$3.14 \times 0.75 \times 0.75 = 1.766\ ft^2$$

$$\frac{inches}{in/ft} = decimal\ ft$$

$$\frac{9}{12} = 0.75$$

Slide 15

8. How many square feet is the end section of a 24-inch pipe?

$$\pi \times R^2 = Area\ ft^2$$

$$3.14 \times 1 \times 1 = 3.14\ ft^2$$

Slide 16

9. How many square feet is the end section of a 36-inch pipe?

$$\pi \times R^2 = Area\ ft^2$$

$$3.14 \times 1.5 \times 1.5 = 7.065\ ft^2$$

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Volume

Volume of a Rectangular Box or Cube

Slides 17-18

Formula: *Volume= Length × Width × Depth*

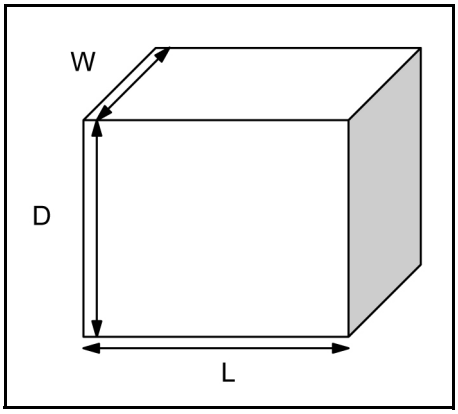

Figure 9.3: Rectangular box/cube.
Source: TEEX.

The length of the box (Figure 9.3) is 6 feet, the width is 3 feet, and the depth is 4 feet. The volume is $6 \times 3 \times 4 = 72$ ft^3.

The little 3 after "ft" is a symbol for cubic units. It means there are three dimensions in the formula.

Volume of a Vertical Cylinder

Slide 19

Formula: *V= πR^2 × Depth*

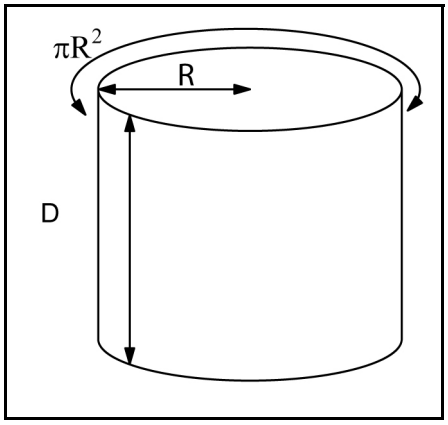

Figure 9.4: Vertical cylinder.
Source: TEEX.

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The cylinder diameter is 20 feet (radius 10') and the depth (D) is 18 feet (Figure 9.4). The volume is 3.14 × 10'× 10' × 18' = 5,652 ft^3.

To calculate the capacity in gallons, multiply cubic feet by 7.48 gal/ft^3.

To calculate the volume in cubic yards, divide cubic feet by 27 ft^3/yd^3.

Volume of a Horizontal Cylinder

Slides 20-21

Formula: *V= πR^2 x Length*

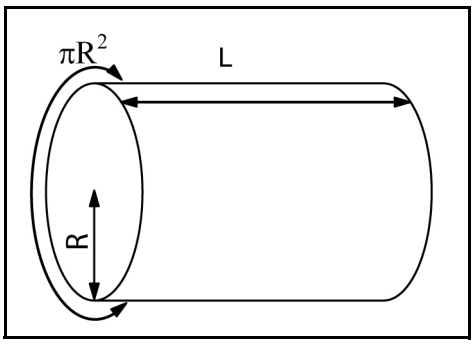

Figure 9.5: Horizontal cylinder
Source: TEEX.

The cylinder (Figure 9.5) is 4 feet in diameter (radius 2') and the length (L) is 9 feet. The volume is 3.14 × 2'× 2' × 9' = 113.04 ft^3.

Multiply cubic feet by 7.48 to calculate capacity in gallons per ft^3.

The following is a shortcut to calculating how many gallons are in a single foot of pipe:

1. Square the diameter of the pipe. (diameter x diameter) or d^2
2. Multiply the result by a factor of 0.0408.
3. Finally, multiply that result by the distance of pipe in feet to calculate total gallons for that distance.

Example for a 6" pipe that is 1' in length:

6 x 6 × 0.0408 × Length (1') = gallons in 1' of pipe

36 x 0.048 x 1 = 1.47 total gallons

Example for a 6" pipe that is 45' in length:

$(6)^2$ × 0.0408 × Length (45') = gallons in 45' of pipe

36 x 0.048 x 45 = 66 total gallons

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Activity 9.2: Volume Calculations

> ***Instructor Note***
>
> *Allow time for the participants to calculate the answers to the following questions. Be sure to answer any questions participants may have.*

Slide 22

1. How many gallons of water will a 20,000-cubic foot tank hold?

$$Vol\ ft^3 \times Gal/ft^3 = Capacity\ Gallons$$

$$20{,}000 \times 7.48 = 149{,}600\ gallons$$

Slide 23

2. How many cubic yards (yd^3) of dirt are removed from a trench that is 60 feet long, 5 feet wide, and 5 feet deep?

$$L \times W \times D = \frac{Volume\ ft^3}{ft^3/yd^3} = yd^3$$

$$60' \times 5' \times 5' = \frac{1{,}500\ ft^3}{27\ ft^3/yd^3} = 55.55\ yd^3$$

Slide 24

3. A rectangular storage tank is 25 feet wide, 40 feet long, and 10 feet deep. What is the volume in cubic feet and capacity in gallons?

$$L \times W \times D = ft^3$$

$$25' \times 40' \times 10' = 10{,}000\ ft^3$$

$$L \times W \times D \times gal/ft^3 = Capacity\ gallons$$

$$10{,}000 \times 7.48 = 74{,}800\ gallons$$

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Slide 25

4. Calculate the cubic yards of dirt removed from a trench 2,000 feet long, 4 feet wide, and 6 feet deep.

$$L \times W \times D = \frac{Volume\ ft^3}{ft^3/yd^3} = yd^3$$

$$2000' \times 4' \times 6' = \frac{48{,}000\ ft^3}{27\ ft^3/yd^3} = 1{,}777.77\ yd^3$$

Slide 26

5. Find the volume in cubic feet (ft^3) and capacity in gallons of a clarifier 60 feet in diameter and 12 feet deep.

$$\pi \times R \times R \times D = Volume\ ft^3$$

$$3.14 \times 30 \times 30 \times 12 = 33{,}912\ ft^3$$

$$Vol\ ft^3 \times Gal/ft^3 = Capacity\ gallons$$

$$33{,}912 \times 7.48 = 253{,}661.76\ gallons$$

Slide 27

6. A sedimentation tank is 55 feet in diameter and 12 feet deep. What is the capacity in gallons?

$$\pi R^2 \times D \times Gal/ft^3 = Capacity\ gallons$$

$$3.14 \times 27.5' \times 27.5' \times 12' \times 7.48 = 213{,}146.34\ gallons$$

Slide 28

7. A chemical mixing tank 15 square feet and 15 feet deep will hold how many gallons of alum?

$$L \times W \times D \times gal/ft^3 = Capacity\ gallons$$

$$15 \times 15 \times 15 \times 7.48 = 25{,}245\ gallons$$

Slide 29

8. A bleach tank has a radius of 3 feet and is 9 feet deep. How many gallons are in the tank if it is only one-quarter full?

$$\frac{\pi \times r^2 \times D \times gal/ft^3}{\frac{1}{4} full} = capacity\ in\ gallons$$

$$\frac{3.14 \times 3 \times 3 \times 9 \times 7.48\ gal/ft^3}{4} = 475.6\ gallons$$

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Slide 30

9. How many gallons will 500 feet of 6-inch pipe hold?

$$\pi R^2 \times L \times Gal/ft^3 = Capacity\ gallons$$

$$\frac{3\ in}{12\ in/ft} = 0.25\ ft\ (radius)$$

$$3.14 \times 0.25 \times 0.25 \times 500\ ft \times 7.48\ gal/ft^3 = 734\ gal.$$

or

$$d\ in^2 \times 0.0408 \times L = Capacity\ gallons$$

$$6\ in \times 6\ in \times 0.0408 \times 500 = 734.4\ gallons$$

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Conversion Factors

Slides 31-32

Table 9.1 provides a list of common conversion factors.

Table 9.1: Conversion Factors

Formulas	
8.34 pounds per gallon	1 acre-foot = 1 acre that is 1 foot deep
7.48 gallons per cubic foot	acre - feet = acres x feet of depth
100 gallons/person/day	27 cubic feet per cubic yard
0.17 lbs. BOD/person/day	5,280 feet per mile
1 acre = 43,560 square feet	1,440 minutes per day
mgd = million gallons per day	1 cubic foot per second (cfs) = 449 gpm
$\frac{\text{part}}{\text{whole}} \times 100$ = percent	$\frac{\text{whole} - \text{part}}{\text{whole}} \times 100$ = percent removal
.433 psi = foot of water column	1 psi = 2.31 feet of water column

Static level is the water level while the pump is off, measured from ground level. Pumping level is the water level while the pump operates, measured from ground level. Drawdown is the difference between static level and pumping level.

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Activity 9.3: Conversion Factor Calculations

> ***Instructor Note***
>
> *Allow time for the participants to calculate the answers to the following questions. Be sure to answer any questions participants may have.*

Slide 33

1. How many gallons of water will a 1,000-cubic foot tank hold?

$$\textbf{Volume } ft^3 \times \textbf{gal/}ft^3 = \textbf{Capacity in gallons}$$

$$1{,}000 \times 7.48 = 7{,}480 \text{ gallons}$$

Slide 34

2. What is the weight of water in a 14,000-cubic foot storage tank?

$$\textbf{Volume } ft^3 \times \textbf{gal/}ft^3 \times \textbf{wt/gal} = \textbf{pounds}$$

$$14{,}000 \times 7.48 \times 8.34 = 873{,}364.8 \text{ pounds}$$

Slide 35

3. How many cubic yards of concrete are needed to fill 108 square feet 1 foot deep?

$$\frac{\textbf{Area } ft^2 \times \textbf{Depth ft}}{ft^3 / yd^3} = yd^3$$

$$\frac{108 \times 1}{27} = 4\ yd^3$$

Slide 36

4. How many 20-foot sections of pipe are needed for 1.5 miles of main?

$$\frac{\textbf{ft/mile} \times \textbf{miles}}{\textbf{joint length}} = \#\ \textbf{sections}$$

$$\frac{5{,}280 \times 1.5}{20} = 396 \text{ sections}$$

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Slide 37

5. What is the mgd flow of a treatment plant producing 800,000 gallons per day?

$$\frac{gallons/day}{1{,}000{,}000} = MGD$$

$$\frac{800{,}000}{1{,}000{,}000} = 0.8\ MGD$$

Slide 38

6. Change 300 gpm to gallons per day. What is the number in mgd?

$$gpm \times min/day = gpd$$

$$300 \times 1{,}440 = 432{,}000\ gpd$$

$$\frac{gpd}{1{,}000{,}000} = mgd$$

$$\frac{432{,}000}{1{,}000{,}000} = 0.432\ mgd$$

Slide 39

7. How many mgd does a 700-gpm pump produce?

$$\frac{gpm \times min/day}{1{,}000{,}000} = mgd$$

$$\frac{700 \times 1{,}440}{1{,}000{,}000} = 1.008\ mgd$$

Slide 40

8. Change 0.5 mgd to gallons per minute.

$$\frac{gal/day}{min/day} = gpm$$

$$\frac{500{,}000}{1{,}440} = 347.2\ gpm$$

Slide 41

9. The static level in a well is 245 feet and the pumping level 308 feet. What is the drawdown?

$$pumping\ level - static\ level = drawdown$$

$$308 - 245 = 63$$

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Slide 42

10. The pumping level of a well is 401 feet. If the drawdown is 19 feet, what is the static level?

$$\textbf{\textit{pumping level - drawdown = static level}}$$

$$\textbf{\textit{401 - 19 = 382}}$$

Slide 43

11. What does a pressure gauge read at the base of a full elevated tank if the water level is 140 feet above the ground?

$$\frac{\textbf{\textit{feet of head}}}{\textbf{2.31}} = \textbf{\textit{psi}}$$

$$\frac{\textbf{140}}{\textbf{2.31}} = \textbf{\textit{60.6 psi}}$$

Slide 44

12. What is the height of a column of water with a base pressure of 43.3 psi?

$$\textbf{\textit{psi}} \times \textbf{2.31} = \textbf{\textit{head in ft}}$$

$$\textbf{43.3 psi} \times \textbf{2.31} = \textbf{100.023 ft}$$

Slide 45

13. A business uses 800 gallons of water per day and is charged $2.50 per 1,000 gallons. What is the cost for a 30-day month?

$$\frac{\textbf{\textit{GDP}} \times \textbf{\textit{\# days}}}{\textbf{\textit{per 1000 gal}} \times \textbf{\$/1,000}} = \textbf{\textit{cost/30 days}}$$

$$\frac{\textbf{\textit{800}} \times \textbf{\textit{30}}}{\textbf{\textit{1000}}} \times \textbf{\textit{2.50}} = \textbf{\textit{\$60.00}}$$

Slide 46

14. A residence has a 1-gallon per minute leak. If the leak is undetected for a 30-day month, what is the cost in wasted water at $3.00 per thousand gallons? Assume the meter reader records only 1,000s of gallons.

$$\frac{\textbf{\textit{GPM}} \times \textbf{\textit{min./day}} \times \textbf{\textit{\# days}}}{\textbf{\textit{per 1,000 gal.}} \times \textbf{\$1,000}} = \textbf{\$/30 days}$$

$$\frac{\textbf{1} \times \textbf{1440} \times \textbf{30}}{\textbf{1,000} \times \textbf{\$3.00}} = \textbf{\$129.60}$$

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Slide 47

15. If treatment reduces a water hardness of 250 mg/L by 60%, what mg/L remains?

Hardness mg/L × % removed = mg/L removed
250 × 0.6 = 150 mg/L

Hardness mg/L – Hardness removed mg/L = remaining hardness
250 – 150 = 100 mg/L
or
Hardness – % remaining = Hardness remaining mg/L
250 × 0.4 = 100 mg/L

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Dosage

To calculate dosage for water treatment, use the following formulas:

$$lbs./day = mgd \times 8.34 \text{ pounds per gallon} \times mg/L$$

$$mg/L = \frac{lbs./gal}{mgd \times 8.34 \text{ pounds per gallon}}$$

Note: The formulas listed above can be thought of in the relationship below (Figure 9.6).

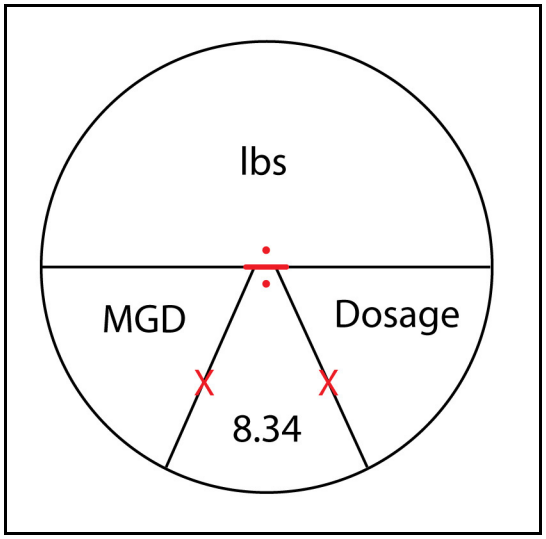

Figure 9.6: Dosage circle. *Source: TEEX.*

Slide 48

$$lbs.\ hypochlorite = \frac{lbs.\ per\ Cl_2}{decimal\ fraction\ hypochlorite}$$

$$Dosage = Demand + Residual$$

$$Demand = Dosage - Residual$$

$$Residual = Dosage - Demand$$

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Activity 9.4: Dosage Calculations

> ***Instructor Note***
>
> *Allow time for the participants to calculate the answers to the following questions. Be sure to answer any questions participants may have.*

Slide 49

1. A sample of treated surface water has a chlorine demand of 3.5 mg/L. If the operator wants a residual of 1 mg/L, what dosage must the operator apply?

   Demand mg/L + Residual mg/L = Dosage mg/L

   3.5 + 1.0 = 4.5 mg/L

Slide 50

2. If an operator applies a chlorine dosage of 2.75 mg/L to 5,000 gallons of treated wastewater and the chlorine demand is 1.25 mg/L, what will be the mg/L residual?

   Dosage mg/L – Demand mg/L = Residual mg/L

   2.75 – 1.25 = 1.5 mg/L

Slide 51

3. An operator applies 7 mg/L of chlorine to effluent containing hydrogen sulfide. If the hydrogen sulfide reacts with all but 2.5 mg/L of the chlorine, what is the chlorine demand?

   Dosage mg/L – Residual mg/L = Demand mg/L

   7.0 – 2.5 = 4.5 mg/L

Slide 52

4. After flushing a fire hydrant for 10 minutes at 200 gpm, a water sample shows a chlorine residual of 4.8 mg/L. If the chlorine demand is 2.2, what is the dosage?

   Demand mg/L + Residual mg/L = Dosage mg/L

   2.2 + 4.8 = 7.0 mg/L

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Slide 53

5. The following alum dosages were applied during surface water treatment:

5 mg/L	*midnight to 6 a.m*
30 mg/L	*6 a.m. to 10 a.m*
25 mg/L	*10 a.m. to 6 p.m.*
15 mg/L	*6 p.m. to midnight*

What is the average dosage per hour for that day?

Procedure: Multiple each dosage by hours applied, total the numbers and divide by 24 hours/day.

$$6\ hrs \times 5 = 30\ mg/L$$

$$4\ hrs \times 30 = 120\ mg/L$$

$$8\ hrs \times 25 = 200\ mg/L$$

$$6\ hrs \times 15 = 90\ mg/L$$

$$30 + 120 + 200 + 90 = 440\ mg/L$$

$$440\ mg/L / 24\ hrs = 18.33\ mg/L$$

Slides 54-55

6. A surface water treatment plant produces 1,600,000 gallons per day using alum at 9 mg/L dosage. How many pounds of alum are used per day, per hour, and per 30-day month?

$$MGD \times wt/gal \times Dosage = pounds\ Alum/day$$

$$1.6 \times 8.34\ lbs./gal \times 9 = 120\ lbs/day$$

$$\frac{pounds/day}{hours/day} = lb./hour$$

$$\frac{120}{24} = 5\ lbs./hour$$

$$lbs./day \times \#\ days = lbs./30\ day$$

$$120 \times 30 = 3{,}600\ lbs.$$

Slide 56

7. An operator is using a 150-pound chlorine cylinder and treating 5,000,000 gallons per day. At a dosage of 1.5 mg/L, is the safe withdrawal rate (vacuum transmission) exceeded if the chlorinator room is $75^{o}F$?

$$MGD \times wt/gal \times Dosage = pounds/day$$

$$5 \times 8.34\ lbs./gal \times 1.5 = 62.5\ pounds,\ so\ NO$$

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Slide 57

8. How many pounds of fluorosilic acid are used daily at a dose of 1 mg/L if a well produces 500 gallons per minute?

$$GPM \times min/day = GPD$$

$$500 \times 1440 = 720{,}000\ GPD$$

$$MGD \times wt/gal \times Dosage = lbs/day$$

$$0.72 \times 8.34\ lbs/gal \times 1.0 = 6\ lbs/day$$

Slide 58

9. Lime is used in a surface water treatment plant at the rate of 480 pounds per day. If the plant produces 2,400,000 gallons daily, what is the mg/L dosage?

$$\frac{lbs.\ chemical/day}{MGD \times wt/gal} = Dosage\ mg/L$$

$$\frac{480}{2.4 \times 8.34\ lbs./gal} = 23.9\ mg/L$$

Slide 59

10. If a well pumps 650 gpm and uses 1.5 pounds of chlorine per hour, what is the mg/L dosage per day?

$$GPM \times min\,/\,day = GPD$$

$$650 \times 1440 = 936{,}000\ PD$$

$$\frac{Cl_2}{lbs./hour} \times hours/day = lbs./day$$

$$1.5 \times 24 = 36$$

$$\frac{lbs.\ chemical/day}{MGD \times wt/gal} = Dosage\ mg/day$$

$$\frac{36}{0.936 \times 8.34\ lbs./gal} = 4.6\ mg/L$$

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Slide 60

11. A water system uses 50 pounds of chlorine per day, but runs out a day before a delivery is made. If calcium hypochlorite (65%) is substituted, will 100 pounds last until delivery? Calculate the answer two ways

$$\frac{\textbf{lbs. of } Cl_2\textbf{/day}}{\textbf{\% Active}} = \textbf{Pounds 65\% needed/day}$$

$$\frac{50}{0.65} = 76.9 \text{ lbs.}$$

$$\textbf{Pounds 65\%} \times \textbf{\% Active} = \textbf{lbs. 100\%}$$

$$100 \times 0.65 = 65$$

Detention Time

Slide 61

Use the following formulas to calculate detention time:

$$\frac{\textit{Tank capacity in gallons}}{\textit{Flow rate}} = \textit{Detention time}$$

$$\frac{\textit{Tank capacity in gallons}}{\textit{Flow rate gpd}} = \textit{Time in days}$$

$$\frac{\textit{Tank capacity in gallons}}{\textit{Flow rate gph}} = \textit{Time in hours}$$

$$\frac{\textit{Tank capacity in gallons}}{\textit{Flow rate gpm}} = \textit{Time in minutes}$$

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Activity 9.5: Detention Time Calculations

> ***Instructor Note***
>
> *Allow time for the participants to calculate the answers to the following questions. Be sure to answer any questions participants may have.*

Slide 62

1. How many minutes will it take to fill a 4,000-gallon wet well at 400 gpm?

$$\frac{\textit{Capacity in gallons}}{\textit{Flow gpm}} = \textit{Fill time in minutes}$$

$$\frac{4{,}000}{400} = 10 \text{ minutes}$$

Slide 63

2. How many hours will it take to empty a 20,000-gallon tank at 60 gpm?

$$\frac{\textit{Capacity in gallons}}{\textit{Flow gph}} = \textit{Fill time in hours}$$

$$\frac{20{,}000}{60 \times 60} = 5.5 \text{ hrs}$$

Slide 64

3. How many days will it take to fill a 300,000-gallon wet well at 100 gpm?

$$\frac{\textit{Capacity in gallons}}{\textit{Flow gpd}} = \textit{Fill time in days}$$

$$\frac{300{,}000}{144{,}000} = 2.08 \text{ days}$$

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Slide 65

4. A sedimentation tank is 75 feet long, 35 feet wide, and 15 feet deep. What is the detention time in hours at a flow rate of 2 mgd?

$$^{\#1}L \times W \times D \times gal/ft^3 = Capacity\ gallons$$

$$75 \times 35 \times 15 \times 7.48 = 294{,}525$$

$$\frac{Capacity\ in\ gallons^{\#1}}{Flow\ gpd} = DT\ in\ hrs$$

Slide 66

$$\frac{2{,}00{,}000\ gallons}{24\ hours} = 83{,}333\ gph$$

$$\frac{^{\#1}294{,}525}{83{,}333} = 3.5\ hrs$$

Slide 67

5. A ground storage tank is 20 feet in diameter and 10 feet deep. At 11 a.m., an operator begins filling it at 500 gpm. Will the operator be late for lunch at noon?

$$\frac{capacity\ in\ gallons}{flow\ GPM} = fill\ minutes$$

$$\frac{23{,}487}{500} = 46.9\ minutes$$

$$\pi \times R^2 \times D \times 7.48\ gal/ft^3 = capacity\ gallons$$

$$(3.14 \times 10' \times 10' \times 7.48\ gal/ft^3) = 23{,}487\ gallons$$

Summary

Slide 68

The formulas and problem calculations reviewed in this module may be applied daily in the water utility industry. It's important to understand the variables, formulas, and results of these mathematical equations.

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Module 9 Presentation Slides

Basic Water Operations

Module 9
Calculations

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Terminal Objective

Upon successful completion of this module, the participant will be able to calculate problems related to basic water operations

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Enabling Objectives

- Calculate the area of squares, rectangles, and circles.
- Calculate volume in cubic feet and gallons of rectangular and cylindrical tanks.
- Solve problems requiring the use of conversion factors.

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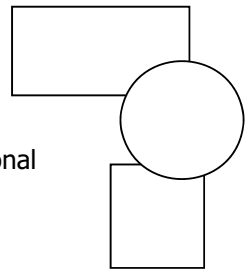
Enabling Objectives (cont.)

- Solve problems involving chemical dosage.
- Solve problems of detention time in days, hours, and minutes.

Area

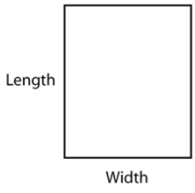
- Rectangle
- Square
- Circle
- A two-dimensional flat plain



Calculating Area

- **Rectangle or Square**
  - Formula: $L \times W = \text{Area ft}^2$
  - Length = 6 feet
  - Width = 5 feet
  - Total surface area calculation:

$$6' \times 5' = 30 \text{ ft}^2$$



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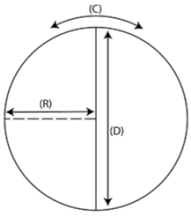
Calculating Area

- **Circle**
  - Formula:
    p x R^2 = Area ft^2
    3.14 x Radius x Radius
  - C = circumference
  - D = diameter
  - R = radius



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Problem 1

Find the bottom surface area of tarp.

L' x W' = surface area ft^2
10 ft x 5 ft = 50 ft^2

Problem 2

Find the area in ft^2 of Cl_2 room roof.

L x W = area ft^2
8 ft x 8 ft = 64 ft^2

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Problem 3

Find the area ft^2 of trench bottom.

L x W = area ft^2
50 ft x 6 ft = 300 ft^2

Problem 4

Find the area ft^2 of circular tank bottom.

$\pi \times R \times R$ = Area ft^2

$\frac{\text{Diameter (D')}}{2}$ = Radius (R')

3.14 x 10 ft x 10 ft = 314 ft^2

Problem 5

Find the area of circular roof.

$\pi \times R \times R$ = area ft^2
3.14 x 17.5 ft x 17.5 ft = 961.6 ft^2

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Problem 6

Find: A. inches square (in^2) end section
B. square feet (ft^2) in end section

A. π x r x r = area in^2
3.14 x 3 in x 3 in = 28.26 in^2

B. π x R x R = area ft^2
(3″ ÷ 12″ = 0.25′)
3.14 x 0.25 ft x 0.25 ft = 0.19625 ft^2

Problem 7

Find the area (ft^2) of end section of pipe.

π x R x R = area ft^2
9″ ÷ 12″ = 0.75′
3.14 x 0.75 ft x 0.75 ft = 1.766 ft^2

Problem 8

Find the area (ft^2) of end section of pipe.

π x R x R = area ft^2
3.14 x 1 ft x 1 ft = 3.14 ft^2

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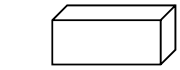
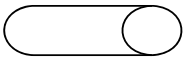
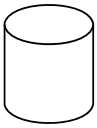
Problem 9

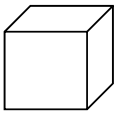
Find the area (ft^2) of end section of pipe.

π x R x R = area ft^2
3.14 x 1.5 ft x 1.5 ft = 7.065 ft^2

Volume

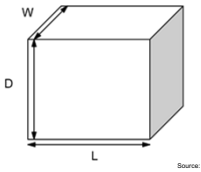
- Rectangular
- Square
- Circular tanks
- Circular pipes



Source: TEEX

Calculating Volume

- **Rectangular box/cube**
  - Formula: L x W x D = Volume ft^3
    Length x Width x Depth =
    Volume ft^3
  - Length=6 ft
  - Width=3 ft
  - Depth=4 ft
  - 6′ x 3′ x 4′ = 72 ft^3



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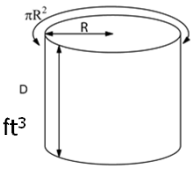
Calculating Volume

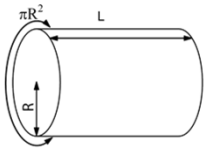
- **Vertical Cylinder**
  - Formula: $\pi R^2 \times D$ = Volume ft^3
    3.14 x Radius x Radius x Diameter = Volume ft^3
    - Diameter = 20 ft
    - Radius = 10 ft
    - Depth = 18 ft
  - 3.14 x $(10')^2$ x 18′ = Volume ft^3
  - 3.14 x 100′ x 18′ = 5,652 ft^3



Source: TEEX

Calculating Volume

- **Horizontal Cylinder**
  - Formula: $\pi R^2 \times L$ = Volume ft^3
    3.14 x Radius x Radius x Length = Volume ft^3
    - Diameter = 4 ft (R=2 ft)
    - Length = 9 ft
  - 3.14 x $(2')^2$ x 9′ = Volume ft^3
  - 3.14 x 4′ x 9′ = 113.04 ft^3



Source: TEEX

Calculating Volume

- Horizontal Cylinder
  - Convert volume ft^3 to gallons
  - 7.48 gallons per ft^3
  - Volume ft^3 x 7.48 = Volume gallons
  - 113.04 ft^3 x 7.48 = 845.54 gallons

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Problem 1

Find capacity in gallons.

Volume in ft^3 x gal/ft^3 = Capacity gal.

20,000 ft^3 x 7.48 gal/ft^3 = 149,600 gallons

Problem 2

Find cubic yards of dirt removed.

$$L \times W \times D = \frac{\text{Vol. } ft^3}{ft^3/yd^3} = yd^3$$

$$60 \text{ ft} \times 5 \text{ ft} \times 5 \text{ ft} = \frac{1500\ ft^3}{27\ ft^3/yd^3} = 55.55\ yd^3$$

Problem 3

Find volume in cubic feet (ft^3).

Find capacity in gallons.

L x W x D = vol. ft^3

40 ft x 25 ft x 10 ft = 10,000 ft^3

Volume in ft^3 x gal/ft^3 = Capacity gal.

10,000 ft^3 x 7.48 gal/ft^3 = 74,800 gallons

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Problem 4

Cubic yards of dirt removed?

$$L \times W \times D = \frac{\text{Vol. ft}^3}{\text{ft}^3/\text{yd}^3} = \text{yd}^3$$

$$2000 \text{ ft} \times 4 \text{ ft} \times 6 \text{ft} = \frac{48{,}000 \text{ ft}^3}{27 \text{ ft}^3/\text{yd}^3} = 1{,}777.7 \text{ yd}^3$$

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Problem 5

Find volume in ft^3 of wet well.

Find capacity of wet well in gallons.

$\pi \times R \times R \times D = \text{vol. ft}^3$

$3.14 \times 30 \text{ ft} \times 30 \text{ ft} \times 12 \text{ ft} = 33{,}912 \text{ ft}^3$

$\text{Vol. ft}^3 \times \text{gal/ft}^3 = \text{capacity gallons}$

$33{,}912 \text{ ft}^3 \times 7.48 \text{ gal/ft}^3 = 253{,}661.76 \text{ gallons}$

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Problem 6

Find gallons in circular tank.

$\pi \times R \times R \times D \times \text{gal/ft}^3 = \text{gallons}$

$3.14 \times 27.5 \text{ ft} \times 27.5 \text{ ft} \times 12 \text{ ft} \times 7.48 \text{ gal/ft}^3 = 213{,}146.34 \text{ gallons}$

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Problem 7

Find gallons of alum.

L x W x D x gal/ft^3 = gallons

15 ft x 15 ft x 15 ft x 7.48 gal/ft^3 = 25,245 gallons

Problem 8

How many gallons when 1/4 full?

π x R x R x D x gal/ft^3 = gallons **when full**

3.14 x 3 ft x 3 ft x 9 ft x 7.48 gal/ft^3 = 1,902.46 gallons Gallons when full x 1/4 full = gallons

1,902.46 gal x 0.25 = 475.6 gallons

Problem 9

Gallons in 6 inch sewer pipe?

π x R x R x L x gal/ft^3 = gallons

3.14 x 0.25 ft x 0.25 ft x 500 ft x 7.48 gal/ft^3 = 733.97 gal.

d″2 x 0.0408 = gal/LF x L = gallons

6″ x 6″ x 0.0408 x 500 ft = 734.4 gallons

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Conversion Factors

- Static level
  - Water level while the pump is off
- Pumping level
  - Water level while the pump operates
- Drawdown
  - Difference between the two

Conversion Factors (Table 9.1)

8.34 lbs/gallon	27 ft^3/yd^3
7.48 gallons/ft^3	5,280 ft/mile
1 psi = 1 ft of water column	1,440 min/day
0.433 psi = 1 ft of water column	mgd = million gal/day

Problem 1

Find how many gallons.

Vol. ft^3 x Gal/ft^3 = Capacity in Gal.
1000 ft^3 x 7.48 gal/ft^3 = gallons
7,480 gallons

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Problem 2

Find the weight of water in the tank.

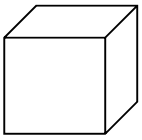
Vol. ft^3 x Gal/ft^3 x wt./gal. = pounds
14,000 ft^3 x 7.48 gal/ft^3 x 8.34 lbs/gal = 873,364.8 lbs

Problem 3

Find the cubic yards of concrete.

$$\frac{\text{Area in } ft^2 \times \text{Depth}}{ft^3/yd^3} = yd^3$$

$$\frac{108\ ft^2 \times 1ft}{27\ ft^3/yd^3} = 4\ yd^3$$



Problem 4

Find how many 20-foot sections of pipe.

$$\frac{\text{Miles of pipe} \times \text{ft/mile}}{\text{Pipe length in ft.}} = \text{Number of Pipes}$$

$$\frac{1.5 \text{ miles} \times 5{,}280 \text{ ft/mile}}{20 \text{ ft/joint}} = 396 \text{ joints}$$

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Problem 5

Find the mgd.

$$\frac{\text{gal/day}}{1{,}000{,}000 \text{ gal/MG}} = \text{Number of Pipes}$$

$$\frac{800{,}000}{1{,}000{,}000} = 396 \text{ joints}$$

Problem 6

Change gpm to gpd and mgd.

$$\text{gpm} \times \text{min/day} = \frac{\text{gal/day}}{1{,}000{,}000 \text{ gal/MG}} = \text{mgd}$$

300 gpm x 1440 min/day =

$$\frac{432{,}000 \text{ gpd}}{1{,}000{,}000 \text{ gal/MG}} = 0.432 \text{ mgd}$$

Problem 7

Change gpm to mgd.

$$\text{gpm} \times \text{min/day} = \frac{\text{gal/day}}{1{,}000{,}000 \text{ gal/MG}} = \text{mgd}$$

700 gpm x 1440 min/day =

$$\frac{1{,}008{,}000 \text{ gpd}}{1{,}000{,}000 \text{ gal/MG}} = 1.008 \text{ mgd}$$

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Problem 8

Change mgd to gpm.

mgd x 1,000,000 gal/MG = $\frac{\text{gal/day}}{\text{min/day}}$ = gpm

0.5 mgd x 1,000,000 gal/MG =

$$\frac{500{,}000 \text{ gal}}{1{,}440 \text{ min/day}} = 347.2 \text{ gpm}$$

Problem 9

What is the drawdown?

Pumping level – Static level = Drawdown
308 ft - 245 ft = 63 ft

Problem 10

What is the static level?

Pumping level – drawdown = static level
401 ft – 19 ft = 382 ft

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Problem 11

Find pressure gauge reading.

$$\frac{\text{Feet of head}}{\text{2.31 feet/psi}} = \text{psi}$$

$$\frac{\text{140 feet}}{\text{2.31 ft/psi}} = 60.6 \text{ psi}$$

Problem 12

Find feet of head.

psi x 2.31 ft/psi = feet of head

43.3 psi x 2.31 ft/psi = 100 feet

Problem 13

Find cost per 30 days.

$$\frac{\text{gpd x \# days}}{\text{per 1000 gal}} \times \$/1000 \text{ gal} = \$$$

$$\frac{\text{800 gpd x 30 days}}{\text{per 1000 gal}} \times \$2.50/1000 \text{ gal} = \$60.00$$

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Problem 14

Find cost of wasted water.

gpm x min/day x # days x $/1000 gal = $ per 1,000 gal

1 gpm x 1440 min/day x 30 days x $3.00/1000 per 1,000 gal = $129.60

Problem 15

Find remaining hardness mg/L.

Hardness mg/L x % remaining = mg/L remaining
250 mg/L x .40 = 100 mg/L

Chemical Dosage

Pounds per day
100%, 65%, 5.25% product
Dosage mg/L
Dosage = Demand + Residual
Demand = Dosage – Residual
Residual = Dosage – Demand

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Problem 1

Find dosage in mg/L.

Demand + Residual = Dosage mg/L
3.5 mg/L + 1.0 mg/L = 4.5 mg/L

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Problem 2

Residual in mg/L?

Dosage – Demand = Residual mg/L
2.75 mg/L - 1.25 mg/L = 1.5 mg/L

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Problem 3

Find chlorine demand.

Dosage - Residual = Demand mg/L
7.0 mg/L - 2.5 mg/L = 4.5 mg/L

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Problem 4

Find dosage in mg/L.

Residual + Demand = Dosage g/L
4.8 mg/L + 2.2 mg/L = 7.0 mg/L

Problem 5

Find average dosage per hour.

5 mg/L x 6 hours = 30 mg/L
30 mg/L x 4 hours = 120 mg/L
25 mg/L x 8 hours = 200 mg/L
15 mg/L x 6 hours = 90 mg/L
Total = $\frac{440 \text{ mg/L}}{24 \text{ hours}}$ = 18.33 mg/L/hour

Problem 6

Find pounds of alum per day.
Find pounds of alum per hour.
Find pounds of alum per month.

MGD x wt./gal x dosage = lbs/day
1.6 x 8.34 x 9 = 120 lbs/day

$$\frac{lbs \ / \ day}{hrs \ / \ day} = lbs \ / \ hr \qquad \frac{120 \, lbs}{24 \, hrs} = 5 \, lbs / hour$$

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Problem 6 (Cont.)

Find lbs. alum for 30-day month.

Pounds/day x day/month = lbs/mo.
120 lbs/day x 30 days/month = 3,600 lbs/month

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Problem 7

Find safe withdrawal rate exceeded.

MGD x wt/gal x dosage mg/L = lbs
5 mgd x 8.34 lbs/gal x 1.5 mg/L =

62.5 lbs
Depends
Vacuum – No Pressure - Yes

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Problem 8

Find pounds of acid.

MGD x wt/gal x dosage mg/L = lbs
gpm x min/day = gpd

500 gpm x 1440 min/day = 720,000 gal
0.72 mgd x 8.34 lbs/gal x 1.0 mg/L = 6.0 pounds

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Problem 9

Find dosage in mg/L .

$$\frac{\text{Lbs of lime}}{\text{mgd x wt/gal}} = \text{dosage in mg/L}$$

$$\frac{480 \text{ pounds}}{2.4 \text{ mgd x } 8.34 \text{ lbs/gal}}$$

23.9 mg/L

Problem 10

Find dosage in mg/L.

$$\frac{\text{Lbs}}{\text{mgd x wt/gal}} = \text{dosage in mg/L}$$

Gpm x min/day = gal/day
650 gpm x 1440 min/day = 936,000 gal
Lbs/hr x hrs/day = lbs/day
1.5 lbs/hr x 24 hrs/day = 36 lbs/day

$$\frac{36 \text{ pounds}}{.936 \text{ mgd x } 8.34 \text{ lbs/gal}} =$$

4.6 mg/L dosage

Problem 11

How many pounds of HTH is needed?

$$\frac{\text{Lbs/day } Cl_2 \text{ used}}{\text{HTH \% active}} = \text{lbs. HTH/day}$$

50 ÷ .65 = 76.92 (Yes)

Pounds HTH x % active = lbs. Cl_2
100 x .65 = 65 lbs (Yes)

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Detention Time

Capacity in gallons
Flow rate = DT

Flow rates GPD = time in days
Flow rates in GPH = time in hrs
Flow rates GPM = time in min

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Problem 1

Find fill time in minutes.

Capacity in gal. = fill time in min
Flow gpm

4,000 gal = 10 minutes
400 gpm

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Problem 2

Find the empty time in hours.

Capacity in gal. = time in hrs
Flow gph

20,000 gal = 3,600 gph = 5.5 hours
60 gpm x 60 min/hr

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Problem 3

Find the fill time in days.

$$\frac{\text{Capacity in gal.}}{\text{Flow gpd}} = \text{fill time in days}$$

$$\frac{300{,}000 \text{ gal}}{100 \text{ gpm} \times 1{,}440 \text{ min/day}} = 144{,}000 \text{ gal/day} = 2.08 \text{ days}$$

Problem 4a

Find the detention time in hours.

$$\frac{\text{Capacity in gal.}^{\#1}}{\text{Flow gph}} = \text{dt in hrs}$$

$^{\#1}$ L x W x D x gal/ft^3 = cap. gal.

75 ft x 35 ft x 15 ft x 7.48 = 294,525 gallons

Problem 4b

$$\frac{\text{Capacity in gal.}^{\#1}}{\text{Flow gph}} = \text{dt in hrs}$$

$$\frac{2{,}000{,}000 \text{ gpd}}{24 \text{ hours}} = 83{,}333 \text{ gph}$$

$$\frac{^{\#1}\ 294{,}525 \text{ gal}}{83{,}333 \text{ gph}} = 3.5 \text{ hrs.}$$

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Problem 5

Find the detention time in minutes.

$$\frac{\text{Capacity of tank in gal.}}{\text{Flow gpm}} = \text{dt min.}$$

π x R x R x L x gal/ft3 = cap. gal.

3.14 x 10 ft x 10 ft x 10 ft x 7.48 gal/ft^3 =

$$\frac{\text{23,487 gallons}}{\text{500 gpm}} = \text{47 minutes}$$

NO

End of Module 9

Next: Course Exam

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Module 10

End-of-Course Activities

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Instructional Guidance

Time

2 hours

Materials/Equipment

1. Participant manual
2. Computer with presentation slides for module 10
3. Internet connectivity
4. Video/data projector
5. Screen or monitor
6. Course Final Exam
7. TEEX Participant Evaluation Survey
8. Certificate of Completion

Instructor Preparation

Prepare projector and position first presentation slide.

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Introduction

During this module, participants will review the course, complete the course examination to assess satisfactory completion of the course, and complete closing activities.

Key Points

Review key points from the following topics that were presented in this course:

- The responsibilities of a water utility operator
- How a water employee can demonstrate good public relations.
- The attributes of water from various sources
- How groundwater is made usable
- How surface water is made usable
- The process for the disinfection of water
- The common methods of water delivery to the public following water treatment
- Proper safety procedures for water employees
- How to calculate problems related to basic water works operations

Course Examination

> ***Instructor Note***
>
> Distribute the WWW001 Final Exam handout. Allow participants adequate time to complete the exam. Review exam answers (see appendix D) with participants and answer any questions from participants.

Participants will complete a 30-question, multiple choice exam. The written final exam will be used as part of the instructor's evaluation for successful completion of the class.

Closing Activities

Complete closing activities.

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Participant Evaluation Surveys

Participants will complete the *TEEX Participant Evaluation Survey*. Upon completion, one participant will collect the surveys, place them in an envelope, and seal the envelope.

Please be sure to answer all questions on both front and back pages of the survey.

Certificates

Instructor Note

It normally takes 15 business days for course materials to be processed and for certificates to be put in the mail. While the certificates will be processed and put into the mailing system within 15 days, mail services may take up to 4 or more weeks for delivery.

Participants who have successfully completed ALL course requirements will receive a *Certificate of Completion* at the end of the class if they were preregistered at least two weeks before the start of the class. If an eligible participant does not receive the certificate at the end of the class, or if the certificate needs to be returned for correction, the certificate will be mailed to the participant.

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Module 10 Presentation Slides

Module 10

End-of-Course Activities

Lessons Learned

Review key points of following topics

- The responsibilities of a water utility operator
- How a water employee can demonstrate good public relations.
- The attributes of water from various sources
- How groundwater is made usable
- How surface water is made usable

Lessons Learned

- The process for the disinfection of water
- The common methods of water delivery to the public following water treatment
- Proper safety procedures for water employees
- How to calculate problems related to basic water works operations

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Course Exam

Course Examination

Final exam
- Written multiple choice test
- 30 questions
- Review

Closing Activities

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Closing Activities

Complete TEEX *Course Feedback Survey*—please answer all questions on both front and back pages.

Closing Activities

Distribute course certificates.

CONGRATULATIONS!

You have completed the course.

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Appendix A

Glossary

Acid. A substance that disassociates in water-forming hydrogen ions.

Acidity. Capacity of an aqueous solution to react with hydroxyl ions.

Aeration. Bringing water into contact with air.

Air gap. An air space between the end of a supply pipe and unsafe or unknown quality water.

Algae. One of single- or multi-celled plant, mostly aquatic and microscopic.

Alum. A coagulant used in water treatment.

Aquifer. A porous, underground, water-bearing formation yielding a useful supply of water.

Artesian well. Groundwater under sufficient pressure to rise above the aquifer containing it.

Atom. The smallest unit of a chemical element composed of protons, neutrons, and electrons.

AWWA. American Water Works Association.

Backfill. The soil or select material placed in an excavation after the pipe is laid.

Backflow. Flow reversal by back siphonage or back pressure higher than supply pressure.

Back pressure. Increase in downstream pressure above the supply pressure.

Bacteria. Microscopic organisms.

Bacteriological samples. Water samples analyzed for microorganisms present.

Basicity. Capacity of an aqueous solution to react with hydrogen ions or pH above 7.

Carbon dioxide. A gas formed by the combustion or decomposition of organics.

Chloramines. Disinfectants formed by the reaction of ammonia with chlorine.

Chlorinator. Device used to apply chlorine to water.

Chlorine. A heavy, greenish-yellow gas with a pungent odor.

Chlorine demand. Amount of chlorine reacted with reducing agents.

Chlorine dosage. Amount of chlorine applied to water in mg/L or ppm.

Chlorine residual. Amount of chlorine remaining after reaction with demand.

Clay. Plastic, earthy, finely divided soil.

Clear well. A ground storage tank at a water treatment plan containing treated water.

Coagulation. Chemical neutralization of suspended and dissolved solids by molecular charges causing clotting.

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Coliform bacteria. Bacteria found on plants, in soil, and in the intestines of warm-blooded organisms.

Combined chlorine residual. Chlorine combined with ammonia (chloramines).

Compliance. Obedience to a requirement.

Contamination. Toxins in water making it unsafe to drink.

Corporation cock. A valve connecting a water main to a service line.

Corrosive. Tendency to destroy or oxidize metal.

Cross connection. A physical connection between a public water system and either another supply of unknown or questionable quality, any source that may contain contaminating or polluting substances, or any source of water treated to a lesser degree in the treatment process.

Detention time. Time water is contained in a tank at a given flow rate.

Disinfection. Killing or inactivation of pathogenic bacteria.

Dissolved solids. Solids in water that cannot be removed by filtration.

Distribution. Transporting water in pipes.

Drain field. Ground receiving septic tank discharge.

Elevated storage. A water tank raised at least 81 feet above the highest service connection.

Employee relations. Relationship between employer and employees.

EPA. Environmental Protection Agency.

Evaporation. The changing of liquid water into vapor.

Fecal. Pertaining to intestinal waste.

Filtration. Removal of suspended material from water by a filter.

Floc. Suspended solids clotted together by chemicals.

Flocculation. The formation of larger floc in water.

Flush. To wash or rinse by water.

Free chlorine residual. Uncombined chlorine after all reactions have taken place.

Gravel pack. Gravel placed around well screens to reduce the intake of sand.

Ground storage. Tanks storing water at ground level.

Groundwater. Water contained in aquifers.

Hard water. Water in which soap lathers poorly, usually caused by calcium and magnesium.

Hazardous atmospheres. Toxic gases, explosive or flammable conditions, oxygen deficiency.

Hydrogen sulfide. Poisonous gas that smells like rotten eggs.

Hydrologic cycle. Natural movement of water between the earth and atmosphere.

Hypochlorination. The use of calcium hypochlorite or sodium hypochlorite to disinfect water.

Hypochlorite. Calcium hypochlorite or sodium hypochlorite.

Impervious. Incapable of penetration, such as by water.

Impurities. Any matter in water.

Indicator organisms. Fecal coliform, which indicate fecal contamination.

Ion exchange. Treatment process in which ions from two different molecules are exchanged.

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Latrine. A ditch or other such receptacle used as a toilet.

Lime. A chemical, calcium oxide, used to increase water alkalinity.

Meter. Measuring device for water flow.

Methane. A gas produced by the anaerobic decay of organic matter.

mg/L. Milligrams per liter equal to parts per million (ppm).

Microorganisms. Microscopic life visible with an optical or electron microscope.

Monitor. To keep track of or record.

Murkiness. Cloudiness caused by suspended particles in water.

Organic. Of human, animal, or vegetable origin, or of carbon structure.

Overpumping. Pumping in excess of recharge.

Percolation. Processed by which water moves downward through soil.

pH. Concentration of the hydrogen ion in gram atoms per liter; neutral water (pH 7) has a hydrogen ion concentration of 10–7.

Positive displacement meter. One of the most common meter designs in the water industry.

Precipitation. Rain, snow, sleet, and hail.

Professionalism. Technical knowledge and ethical standards of a profession.

Public relations. Relationship between the water utility and the public.

PVC. Polyvinyl chloride; a plastic used for pipe.

Reservoir. Body of water stored for public use or a water storage tank for public use.

Respirator. Device worn over the mouth and nose for protection from gases or mists.

Reverse osmosis. Dissolved and suspended solid removal under pressure by membrane filtering.

Runoff. Precipitation that runs off into lakes and streams.

Sanitation. Cleanliness.

Scale. Mineral deposits formed on surfaces.

Sedimentation. Settling of floc or suspended matter in a sedimentation basin.

Settled solids. Suspended solids settled to the bottom of a tank.

Silt. Fine soil suspended in water.

Sludge. Settled floc or suspended solids.

Sodium. An element and component of table salt (sodium chloride).

Sodium thiosulfate. A chemical used to neutralize chlorine.

Softening. Removal or counteracting hardness.

Spoil bank. Excavated material piled along the ditch.

Spring. Where an aquifer reaches the surface.

Standpipe storage. A tank standing on the ground greater in height than width.

Stuffers. Public information included with the monthly utility bill.

Subsidence. Sinking of land due to groundwater withdrawal; common on the coast.

Surface water. Water in lakes, streams, rivers, and reservoirs.

Suspended solids. Solids that can be removed by filtration.

TDSHS. Texas Department of State Health Services.

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Total chlorine residual. Combined chlorine residual plus free chlorine residual.

Total solids. Suspended and dissolved solids combined.

Toxic. Poisonous.

Transpiration. Evaporation of water vapor from plants into the atmosphere.

Transportation. Carried from one point to another.

Trench. A ditch deeper than its width.

Turbidity. Suspended particles that scatter light.

Tuberculation. Buildup of calcium carbonate or other deposits.

TCEQ. Texas Commission on Environmental Quality.

Usage. Amount of water used.

Valve. Device used for controlling water.

Water table. Top surface of an unconfined aquifer.

Well casing. A pipe cemented into an aquifer, preventing well collapse and contamination.

Well screen. A slotted, drilled, or wire-wrapped pipe of corrosion-resistant material used to block sand.

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Appendix B

Chlorine Procedures

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Analytical Methods

Two methods will be summarized in this manual:

- DPD-FAS Titrimetric: Standard Methods 4500-Cl F
- DPD Spectrophotometric: Standard Methods 4500-Cl G

Refer to each method and follow all procedure steps as written.

Chemistry of DPD Ferrous Titrimetric Analysis

Chlorine and **chloramines** *stoichiometrically* liberate **iodine** from **potassium iodide** at pH 4.0 or less. The **iodine** is titrated with **ferric ammonium sulfate (FAS)** using **N,N-diethyl-p-phenylenediamine (DPD)** as the indicator. The results are calculated as mg/L Cl even though the actual measurement is of the total oxidizing power because **chlorine** is the dominant oxidizing agent present.

Stoichiometrically: Calculation of the quantities of reactants and products in a chemical reaction; can be described as the *quantitative* relationship between reactants and products in a chemical reaction.

Definitions

- **Titration**—a method of analysis that will allow you to determine the precise endpoint of a reaction and therefore the precise quantity of reactant in the titration flask.
- **Oxidation**—the addition of oxygen to a compound.
- **Reactive**—readily susceptible to chemical changes.
- **Reagent**—substance or solution utilized to produce a characteristic chemical reaction in an analysis.

Theory of Analysis

DPD indicator and **phosphate buffer** are added to a 100.0 mL sample. When chlorine is present, a red color is formed. Titrate the sample with standard **FAS** until the red color disappears. When 100.0 mL of sample is analyzed, the total milliliters of **FAS** titrated will equal the milligram per liter of **a chlorine residual** that is present. An analytical blank and a known chlorine standard are required QA/QC for this procedure.

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Sampling

An adequate amount of sample for the analysis is required and a minimum 2 liters should be collected if the pH is to be adjusted. The sample must be analyzed as soon as possible upon collection. Overfill the sample bottle to avoid airspace between the cap and sample.

Interferences

pH

A pH between 6.20 and 6.50 is essential to produce sharp, colorless end points.

A high pH may cause dissolved oxygen to produce a false color. Too low of a pH in the first step tends to make the **monochloramine** show in the free-chlorine step. As a result, the **dichloramine** will appear in the **monochloramine** step. The chemical buffers contain materials that will adjust to the proper pH in most drinking water samples.

When performing the analysis on waters with high alkalinities, the pH must be adjusted with a diluted solution of sulfuric acid (**H_2SO_4**) to near 7.00 before proceeding.

Samples having a low pH can be adjusted to pH 7.00 with a dilute sodium hydroxide (**NaOH**) solution.

Manganese (Mn)

Oxidized manganese will cause result increase interferences. The procedure will discuss the techniques for Mn removal.

High Chlorine Residuals

High chlorine residuals, in excess of the capacity of the reagents, will produce a temporary red color followed by a yellow color. Repeat the analysis using samples accurately diluted to 100.0 mL. Formulate the required dilutions before proceeding to the analysis.

DPD-Ferrous Titration Procedure Summary

Apparatus

- 10 or 25 mL Class “A” buret and ring-stand assembly
- Five 250 mL Pyrex Erlenmeyer flasks
- Three 100 mL graduated cylinders

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- Stir plates and bars
- 5 and 10 mL Class "A" volumetric pipets

Reagents

- **DPD** indicator (in powder form or solution)
- **0.0028N Ferrous Ammonium Sulfate (FAS)**
- **Potassium iodide (KI)** crystals
- **Chlorine** primary standard (as example: 1.00 mg/L)
- **0.25% Sodium arsenite** solution, or **Thioacetamide** solution
- DI-H_2O
- **Phosphate buffer** solution
- Dilute sulfuric acid (**H_2SO_4**) solution
- Dilute sodium hydroxide (**NaOH**) solution

Analysis and Apparatus Set-Up

Step 1. Label five Erlenmeyer flasks as follows:

- Blank
- Standard
- Sample
- Duplicate
- Mn Correction

Step 2. Prepare sample as follows:

- Adjust pH if necessary.
- Prepare dilutions if chlorine residual is >5.0 mg/L.

Step 3. Prepare titration apparatus and buret as follows:

- Fill buret to just above the "zero" line with FAS solution.
- Drain excess FAS to eye level ("zero" line at the meniscus).
- Center stir-plate under the buret.

Laboratory Wet-Chemistry Technique

Since there is an increased number of procedure "steps" in the usage of liquid reagents in this method, the procedure summarized is for use of such. Proper laboratory technique is imperative when utilizing this procedure. Follow each step as written in *Standard Methods*.

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Therefore, when using liquid solutions, they must be dispensed in each flask before the sample. Additionally, when titrating, use proper technique to ensure that when the end point becomes immediately clear, do not exceed one drop. One drop is the equivalent of 0.05 mg/L. Titrate slowly with a gentle mixing of the sample.

Free Chlorine Residual

Step 1. Pipet 5.0 mL of phosphate buffer solution to each of the five flasks.

Step 2. Pipet 0.5 mL of sodium arsenite or thioacetamide solution to the "Mn Correction" flask.

Step 3. Pipet 5.0 ml of DPD indicator solution to each flask except the "Mn Correction" flask.

Analyses

Blank. Accurately measure 100.0 mL of laboratory distilled water to the "Blank" flask.

- If a pink color appears, titrate immediately with FAS to a clear endpoint. Record mL used as "Reading C."
- If no pink color appears, titration is not necessary. Record 0.0 mL as "Reading C."

Sample. Accurately measure 100.0 mL of the water sample to the "Sample" flask.

- If a pink color appears, titrate immediately with FAS to a clear endpoint. Record mL used as "Reading A."
- If no pink color appears, titration is not necessary. Record 0.0 mL as "Reading A."

Duplicate Sample. Repeat as above for the "Sample."

Standard. Accurately measure 100.0 mL of the 1.00 mg/L Chlorine Standard to flask marked "Standard."

- Titrate immediately with FAS to a clear endpoint. Record mL of used as "Reading E." The milliliter of FAS titrated should be equal to 1.00 mL if the standard was 1.00 mg/L as Cl_2.
- If no pink color appears, you will need to verify that the standard was properly prepared; if not, remake the standard to ensure your required QA/QC procedures are carefully adhered to.

Manganese Correction. Accurately measure out 100.0 mL of sample to flask marked "Mn Correction."

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Titrate immediately with FAS to a clear endpoint. Record mL used as "Reading D." Subtract "D" from "A."

Total Chlorine as Combined. Step 1, add to each 100.0 mL of the "Sample" and "Duplicate" flasks one very crystal of potassium iodide (KI). Mix and let stand for three (3) minutes. Step 2, titrate the solution with FAS to a clear endpoint. Record mL used as "Reading B."

Calculation Formulas

A = mL titrated for sample as free chlorine

B = mL titrated for sample as total chlorine (after KI addition)

C = mL titrated for blank

D = mL titrated for manganese (Mn) correction sample

E = mL titrated for standard

N = Normality of FAS titrant

Blank:

$$\frac{C \times N \times 35{,}450}{mL\ sample}$$

Samples & Duplicates:

$$\frac{(A - D) \times N \times 35{,}450}{mL\ sample}$$

Then, multiply by 100 to report result as a percentage (%) deviation.

Manganese Correction:

$$\frac{D \times N \times 35{,}450}{mg/L\ results\ of\ sample}$$

QA/QC Standard Recovery:

$$\frac{E \times N \times 35{,}450}{mg/L\ results\ of\ sample}$$

Then, multiply by 100 to report result as a percentage (%) recovery.

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Chlorine Species Formulas

Free Chlorine Residual

mg/L chlorine residual from "A" titration – Mn correction mg/L

Combined Chlorine Residual

mg/L chlorine residual from "B" titration – Mn correction mg/L

Total Chlorine Residual

Free + Combined = Total mg/L

DPD Spectrophotometric

Chemistry of DPD Spectrophotometric Analysis

Chlorine can be present in drinking water as **free chlorine** and as **combined chlorine**. Both forms can exist in the same water and be determined together as the **total chlorine**. Free chlorine is present as **hypochlorous acid (HOCl)** or **hypochlorite ion (OCl-)**.

Combined chlorine exists as **monochloramine**, **dichloramine**, and **nitrogen trichloride (trichloramine)**. The combined chlorine oxidizes iodide in the reagent to **iodine**. The **iodine** and free chlorine reacts with **N,N-diethyl-p-phenylenediamine (DPD)** to form a red color that is proportional to the total chlorine concentration:

$$NH_2Cl + 3I^- + H_2O + H^+ \rightarrow NH_4OH + Cl^- + I_{3^-}$$

$$NHCl_2 + 3I^- + H_2O + 2H^+ \rightarrow NH_4OH + 2Cl^- + I_{3^-}$$

Monochloramine and **dichloramine** are slow to react directly with DPD at a near neutral pH. To quantify these species, the test is carried out in slightly acidic conditions in the presence of the **iodide ion**.

To resolve the concentration of combined chlorine, analyze for free chlorine, then analyze for total chlorine. Subtract the results of the free chlorine assay from the total chlorine assay to calculate the combined chlorine concentration. Test results are measured at 530 nm **(nanometer)** on a **spectrophotometer**.

Nanometer: Unit of measurement of light wavelength. A nanometer is one-millionth of a millimeter. Expressed as: 10–9.

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Spectrophotometer: An instrument that measures the photometric intensity of each color or wavelength present in the optical spectrum.

Sampling

Analyze samples for chlorine immediately after collection:

Free chlorine is a strong oxidizing agent and it is unstable in natural waters. Chlorine reacts rapidly with a number of **inorganic** compounds and more slowly oxidizes **organic** compounds. Various factors, including reactant concentrations, sunlight, pH, temperature, and salinity influence decomposition of free chlorine in water.

Avoid plastic containers:

Plastics produce chlorine demand and can reduce the actual chlorine residual of the sample. Pretreat glass sample containers to remove any chlorine demand by soaking in a dilute bleach solution (1.0 mL commercial NSF bleach to l liter of DI-H_2O) for at least one hour. Rinse thoroughly with distilled water. If sample containers are rinsed thoroughly with distilled water after each use, only occasional pretreatment is necessary.

Do not use the same sample cells for free and total chlorine:

If trace iodide from the total chlorine reagent is carried over into the free chlorine determination, monochloramine will interfere. It is best to use separate, dedicated sample cells for free and total chlorine determinations.

A common error in testing for chlorine is not obtaining a representative sample:

When sampling from a tap, let the water flow for at least five minutes to ensure a representative sample. Let the container overflow with the sample several times, then cap the sample containers so there is no headspace (air) above the sample. If sampling with a sample cell, rinse the cell several times with the sample, then carefully fill to the 10-mL mark. Perform the chlorine analysis immediately.

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DPD Powder-Pillow Method

For this course we will summarize the HACH DPD Powder-Pillow Method. This procedure is accepted by the TCEQ for analyses of both free and total chlorines in potable water. There are several other methods and laboratory manufacturer's testing kits available on the market for chlorine testing; please refer to Standard Methods or the TCEQ to assure that those procedures or products meet the 30TAC approval criteria before using for permit requirements.

Table B.1: Interferences *(Courtesy of HACH Water Analysis Handbook, 4th Edition)*

Interfering Substance	Interference Levels and Treatments
Acidity	Greater than 150 mg/L $CaCO_3$. May not develop full color or color may fade instantly. Neutralize to pH 6-7 with 1 N sodium hydroxide. Determine amount to be added on separate sample aliquot, then add the same amount to the sample being tested. Correct for volume addition.
Alkalinity	Greater than 300 mg/L $CaCO_3$. May not develop full color or color may fade instantly. Neutralize to pH 6-7 with 1 N sulfuric acid. Determine amount to be added on separate sample aliquot, then add the same amount to the sample being tested. Correct for volume addition.
Bromine, Br_2	Interferes at all levels
Chlorine Dioxide	Interferes at all levels
Chloramines, organic	May interfere
Hardness	No effect at less than 1,000 mg/L as $CaCO_3$
Iodine, I_2	Interferes at all levels
Manganese, Oxidized (Mn^{4+}, Mn^{7+}) or Chromium, Oxidized (Cr^{6+})	1. Adjust sample pH to 6-7. 2. Add 3 drops potassium iodide (30 g/L) to a 25 ml sample. 3. Mix and wait one minute. 4. Add 3 drops sodium arsenite (5 g/L) and mix. 5. Analyze 10 mL of the treated sample as described in the procedure. 6. Subtract the result from this test from the original analysis to obtain the correct chlorine concentration.
Ozone	Interferes at all levels
Peroxides	May interfere
Extreme sample pH or highly buffered samples	Adjust to pH 6-7 using acid (Sulfuric Acid, 1.000 N) or base (Sodium Hydroxide, 1.00 N).

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Method Summary

Be sure to carefully read and follow all procedure directions that are described in the operating manual and analysis methods.

1. Fill a round sample cell with 10 mL of sample (Figure B.1).

Figure B.1: 10-mL sample cell

2. Add the contents of one DPD Total Chlorine Powder Pillow to the sample cell. (This is the prepared sample.) Swirl the sample cell for 20 seconds to mix (Figure B.2).

Figure B.2: Chlorine powder pillow action

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3. Time: A three-minute reaction period will begin. Perform steps 4 and 5 during this time period (Figure B.3).

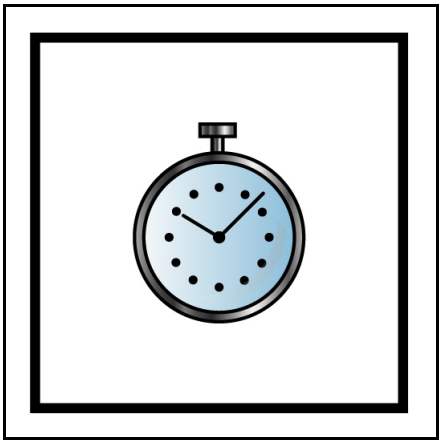

Figure B.3: Three-minute reaction period

4. Fill another round sample cell with 10 mL of sample. (This is the blank.) Wipe the sample cell and place it into the cell holder (Figure B.4).

Figure B.4: 10-mL sample cell

5. Touch Zero. The display will show: 0.00 mg/L Cl_2.

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6. Within three minutes after the timer beep, wipe the prepared sample and place it into the cell holder. Results will appear in mg/L Cl_2 (Figure B.5).

Figure B.5: Place sample in cell holder

7. Repeat the above procedures this time utilizing the DPD Free Chlorine Pillow. You will not have to wait the three-minute reaction time for free chlorine, mix as described and place in analyzer and press read.

Quality Assurance/Quality Control

30 TAC §290.46: Minimum Acceptable Operating Practices for Public Drinking Water Systems

(2) Laboratory equipment used for compliance testing shall be properly calibrated.

(C) Disinfectant residual analyzers shall be properly calibrated.

(i)The accuracy of manual disinfectant residual analyzers shall be verified at least once every 30 days using chlorine solutions of known concentrations.

(ii)Continuous disinfectant residual analyzers shall be calibrated at least once every 90 days using chlorine solutions of known concentrations.

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(iii)The calibration of continuous disinfectant residual analyzers shall be checked at least once each month with a chlorine solution of known concentration or by comparing the results from the on-line analyzer with the result of approved benchtop amperometric, spectrophotometric, or titration method.

The Pocket-Colorimeter from HACH is classified as a spectrophotometric analyzer.

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Appendix C

Water Operator Licensing Rules and Testing Information

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Water Operator Licensing Rules

SUBCHAPTER K: PUBLIC WATER SYSTEM OPERATORS AND OPERATIONS COMPANIES
§§30.381, 30.387, 30.390, 30.392, 30.396, 30.398, 30.400, 30.402
Effective September 29, 2016

§30.381. Purpose and Applicability.

(a) The purpose of this subchapter is to establish qualifications for issuing and renewing licenses and registrations to:

(1) public water system operators who perform process control duties in production or distribution of drinking water; and

(2) operations companies that operate public water systems on a contractual basis.

(b) A person who performs any of the tasks listed in subsection (a) of this section must meet the qualifications of this subchapter and be licensed or registered according to Subchapter A of this chapter (relating to Administration of Occupational Licenses and Registrations), unless exempt under §30.402 of this title (relating to Exemptions); and must comply with the requirements in Chapter 290 of this title (relating to Public Drinking Water).

(c) Public water system operator licenses, certificates of competency, and registrations issued before January 1, 2002, remain in effect until they expire, or are replaced, or revoked by the commission.

(d) Renewable Class D licenses, previously issued to individuals who did not possess a high school diploma or equivalent certificate may be renewed according to §30.392 of this title (relating to Qualifications for License Renewal).

(e) An individual that is issued a license under this subchapter must perform adequate process control duties as recognized by current best management practices.

(f) An individual who has an honorary license shall not perform process control duties in production or distribution of drinking water for a public water system.

Adopted September 5, 2007 Effective September 27, 2007

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§30.387. Definitions.

The following words and terms, when used in this subchapter, shall have the following meanings, unless the context clearly indicates otherwise.

(1) Chief operator--An individual who has overall responsibility for the operation of a public water system.

(2) Honorary license--License converted from a perpetual license that has been discontinued by the commission. This honorary license does not award the licensee the authority to perform process control duties in production or distribution of drinking water for public water systems.

(3) Military operator-in-training--An individual who is an active duty member of the military of the United States and has successfully completed the Bioenvironmental Engineering Apprentice (BEA) or equivalent military training, as determined by the executive director, and collects microbiological samples and determines disinfection residuals for military facilities' water distribution systems. This individual may not perform any other process control duties in the water distribution or treatment facilities of a military installation.

(4) Operator-in-charge--An individual who has overall responsibility for the operation of a public water system in the absence of the chief operator.

(5) Operator-in-training--An unlicensed individual entering the field of public water system operation for the first time who has less than one year of experience and is in training to perform process control duties in production or distribution of public drinking water.

(6) Public water system operations company--A person or other nongovernmental entity that provides operations services to one or more public water systems on a contractual basis.

(7) Public water system operator--Licensed operator who performs process control duties in production or distribution of drinking water.

(8) Work experience--The actual performance of job tasks in a public water supply system that are considered essential for the treatment or distribution of drinking water.

Adopted December 5, 2012 Effective December 27, 2012

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§30.390. Qualifications for Initial License.

(a) To obtain a license, an individual must meet the requirements of Subchapter A of this chapter (relating to Administration of Occupational Licenses and Registrations), and the following requirements for each class of license, and pass an examination.

Figure: 30 TAC §30.390(a)

License	Education	Work Experience	Training Credits
Class D	High School Diploma (HSD) or equivalent	None	20 hours
Class C, Distribution, Groundwater, Surface water	HSD or equivalent	2 years	60 hours
Class B, Distribution and Groundwater	Bachelor's HSD or equivalent	2½ years 5 years	120 hours 120 hours
Class B, Surface water	Bachelor's HSD or equivalent	2½ years 5 years	144 hours 144 hours
Class A	Master's Bachelor's HSD or equivalent	4 years 5 years 8 years	184 hours 184 hours 184 hours

(b) An individual who applies for a Class C, B, or A license, and relies on a bachelor's or master's degree to meet the educational requirements, must have a bachelor's or master's degree with a major in chemistry, biology, engineering, microbiology, bacteriology, or other similar discipline approved by the executive director.

(c) An individual who applies for a Class C or B license must obtain at least one-half of the total work experience requirement in the specific field for the license that is requested:

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(1) for Class C and B surface water licenses, the experience must be obtained through operations activities at the production or treatment facilities for surface water or groundwater under the direct influence of surface water;

(2) for Class C and B groundwater licenses, the experience must be obtained through operations activities at the production or treatment facilities for groundwater source or groundwater under the direct influence of surface water; or

(3) for Class C and B distribution licenses, at least one-half of the required experience must be obtained as a result of operations activities at treated water storage, pumping, or distribution facilities; and

(4) once the work experience has been met from paragraphs (1), (2), or (3) of this subsection, the executive director may count any remaining experience to meet up to 50% of the remaining requirement.

(d) For all classes of licenses, laboratory experience must:

(1) be obtained at a laboratory that is owned and operated by the public water system; and

(2) involve daily consultation with individuals who perform process control duties in production or distribution of drinking water for the water system.

(e) For each license, applicants may substitute either college hours or training credits to meet the experience requirement:

(1) 16 semester hours or an additional 20 hours of training credits are equal to six months of the experience;

(2) Class C applicants may only substitute up to one year of the required work experience; and

(3) Class B and Class A applicants may only substitute up to two years of the required work experience.

(f) Training credits must be in approved courses that include the following or equivalent.

Figure: 30 TAC §30.390(f)

License	Core Training Courses	Elective Training Courses
Class D	Basic Waterworks Operation	None

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Class C Surface Water	Basic Waterworks Operation Surface Water Production I Surface Water Production II	None
Class C Groundwater	Basic Waterworks Operation Groundwater Production Plus one elective course	Water Distribution Water Laboratory Water Utility Safety Water Utility Calculations Chlorinator Maintenance Pump and Motor Maintenance Valve and Hydrant Maintenance
Class C Water Distribution	Basic Waterworks Operation Water Distribution Plus one elective course	Water Laboratory Water Utility Safety Water Utility Calculations Chlorinator Maintenance Pump and Motor Maintenance Valve and Hydrant Maintenance.
Class B Surface Water	Basic Waterworks Operation Surface Water Production I Surface Water Production II Water Distribution Water Utility Safety Water Laboratory Water Utility Management	None
Class B Groundwater	Basic Waterworks Operation Groundwater Production Water Laboratory Water Distribution Water Utility Safety Plus one elective course	Water Utility Management Water Utility Calculations Chlorinator Maintenance Pump and Motor Maintenance Valve and Hydrant Maintenance
Class B Water Distribution	Basic Waterworks Operation Water Distribution Water Utility Safety Pump and Motor Maintenance Valve and Hydrant	Water Utility Management Water Utility Calculations Chlorinator Maintenance Water Laboratory

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	Maintenance Plus one elective course	
Class A	Basic Waterworks Operation Surface Water Production I Surface Water Production II Groundwater Production Water Distribution Water Laboratory Water Utility Management Water Utility Safety	Plus additional training to meet the 184 hour requirement

(g) An individual who previously held a Class D license shall not apply for a new Class D license if the individual:

(1) currently operates facilities at groundwater treatment systems of 250 connections or more;

(2) currently operates facilities at groundwater treatment systems serving a population of 750 or more;

(3) currently operates facilities at surface water treatment systems;

(4) currently operates facilities at groundwater systems under the influence of surface water;

(5) performs supervisor, crew chief, or foremen duties for distribution systems that have over 250 connections; or

(6) operates multiple groundwater systems and the cumulative number of connections exceeds 250.

Adopted September 7, 2016 Effective September 29, 2016

§30.392. Qualifications for License Renewal.

(a) To renew a license, an individual must have:

(1) met the requirements of Subchapter A of this chapter (relating to Administration of Occupational Licenses and Registrations) and completed a total amount of approved continuing education equal to that of ten hours per year the license is valid; or

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(2) met the requirements of Subchapter A of this chapter and passed the examination for the license.

(b) The basic water training course shall not be used to renew a Class B or A license.

(c) Class D licenses are not renewable for licensed operators:

(1) at groundwater treatment systems of 250 connections or more;

(2) at groundwater treatment systems serving a population of 750 or more;

(3) at surface water treatment systems;

(4) at groundwater systems under the influence of surface water;

(5) who are supervisors, crew chiefs, or foremen of distribution systems that have over 250 connections; or

(6) who operate multiple groundwater systems and the cumulative number of connections exceeds 250.

(d) To renew an active converted perpetual license, an individual must have met the requirements of this section, with the exception of the renewal fee.

Adopted September 5, 2007 Effective September 27, 2007

§30.396. Qualifications for Initial Registration.

To obtain a registration, a person must meet the requirements of Subchapter A of this chapter (relating to Administration of Occupational Licenses and Registrations).

Adopted November 20, 2001 Effective December 17, 2001

§30.398. Qualifications for Registration Renewal.

To renew a registration a person must meet the requirements of Subchapter A of this chapter (relating to Administration of Occupational Licenses and Registrations).

Adopted November 20, 2001 Effective December 17, 2001

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§30.400. Additional Requirements for Public Water System Operations Companies.

(a) When a public water system operating company submits an application to obtain or renew a registration, it must submit a report to the executive director. The report shall include:

(1) the public water system operating company name, registration number, location, and mailing address;

(2) the public water system identification number and name for each system operated;

(3) the dates of operation during the reporting period;

(4) the names and license numbers of all licensed operators employed by the operations company;

(5) the names of the licensed chief operators and licensed supervisors; and

(6) any additional information required by the executive director.

(b) A person that operates a public water system under contract must apply for a new registration and submit an amended report if a company is bought or sold and the name of the company changes.

(c) Public water system operating companies shall submit a registration fee based on the number of public water systems served as indicated in the following table.

Figure: 30 TAC §30.400(c)

Number of Public Water Systems Served	**Fee**
0 to 4	$122
5 to 9	$240

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10 to 19	$399
20 or more	$636

Adopted September 5, 2007 Effective September 27, 2007

§30.402. Exemptions.

(a) An individual who performs process control duties in production or distribution of drinking water for a transient non-community water system as defined in §290.38(77) of this title (relating to Definitions), is exempt from the licensing requirements of this subchapter, if the source water for the water system is purchased treated water or groundwater that is not under the direct influence of surface water.

(b) An operator-in-training under the direct supervision of a licensed public water system operator is exempt from the licensing requirements of this subchapter.

(c) A military operator-in-training under the direct supervision of a licensed public water system operator is exempt from the licensing requirements of this subchapter for the purpose of collecting microbiological samples or determining disinfection residuals at military facilities' water distribution systems. The military operator-in-training is not exempt from the licensing requirements of this subchapter for the purpose of performing any other process control duties in the distribution or treatment facilities of a public water system.

(d) An individual who holds a groundwater or surface water license may perform duties relating to the operation and maintenance of drinking water production, purchased water, and water distribution systems and is not required to hold a distribution license.

Adopted December 5, 2012 Effective December 27, 2012

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TCEQ Testing

Beginning September 1, 2016, the TCEQ is planning to initiate a preapproval process for all new license applications. This process will be similar to the process already used for preapproving "A" Water or Wastewater license applications and CBT applications. This means that new license applicants will not be eligible to register for an exam until their application is administratively complete, approved by the TCEQ, and they receive a letter from the TCEQ notifying them they are eligible to register for an exam session.

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TCEQ Test Locations and Dates

Texas Commission on Environmental Quality

MC-178 P.O. Box 13087

Austin, Texas 78711-3087

Exam Schedules

https://www.tceq.texas.gov/licensing/exams/registration

Exam Results and Training Records

https://www.tceq.texas.gov/licensing

TCEQ licensing exams are administered at the central and regional offices on a monthly basis. To take an exam, you must register online (see above website) for an available seat and pay your application fee via the TCEQ ePay system.

Exam results should be posted on the website within four weeks of your exam date and mailed to you within six weeks of your exam date. To ensure timely processing, **please do not call the TCEQ for exam results unless it has been over six weeks since your exam date.**

Exam sessions administered in the TCEQ Regional Offices may be cancelled during holidays and during the months coinciding with regional conferences scheduled in their area.

Please contact your Regional Office to confirm scheduled exam dates and times and please arrive at your designated exam site on time as scheduled.

What to bring to the exam site: No. 2 pencils, your employment history, copies of training course completion certificates or cards, copies of college transcripts, non-programmable calculator, and a photo I.D. card (driver's license). *Note: Cell phone usage is not permitted in the examination room (including the calculator function).*

To request special accommodations in compliance with the Americans with Disabilities Act, please contact the Austin Central Office at 512/239-6133.

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Computer-Based Testing for Occupational Licenses

Take your license examination on a computer!

CBT license examinations offer:

Computer-Based Testing
Instant Test Results
Instant Re-Testing
Multiple Locations
The TCEQ offers Computer-Based Testing for individuals seeking an Occupational License.

- The convenience of numerous CBT exam sites
- Daily access and expanded hours to CBT exam sites
- Immediate exam score with e-mail option
- Immediate printed exam analysis feedback with e-mail option
- License issued to applicants passing CBT exam within one week of exam date
- Immediate retesting, if the exam site has available seating (4 attempts per application)
- User-friendly computer screens

Examinations available for CBT by Licensing Program

- **Backflow Prevention Assembly Tester**
- **Customer Service Inspectors**
- Landscape Irrigation
  - **Landscape Irrigation Inspector**
  - **Landscape Irrigation Technician (English Only)**
- Municipal Solid Waste Facility Supervisors
  - **Class A**
  - **Class B**
- On-site Sewage Facility (OSSF)
  - **OSSF Maintenance Provider**
- Wastewater Treatment and Collection System Operators
  - **Class I Wastewater Collection System Operator**
  - **Class B Wastewater Treatment Facility Operator**
  - **Class C Wastewater Treatment Facility Operator**
  - **Class D Wastewater Treatment Facility Operator**

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- Water Treatment and Distribution System Operators
  - **Class B Groundwater Operator**
  - **Class B Surface Water Operator**
  - **Class B Water Distribution**
  - **Class C Groundwater Operator**
  - **Class C Surface Water Operator**
  - **Class C Water Distribution**
  - **Class D Water**
- Water Treatment Specialists
  - **Class III**
  - **Class II**
  - **Class I**

Pre-approval of your licensing application is required. For pre-approval, applicants must:

- complete license requirements—
  - education
  - experience
  - training
- submit an application with the $111 processing fee to TCEQ Occupational Licensing, MC-178, PO Box 13087, Austin, TX 78711-3087
- To obtain an application, go to the **CBT Application Request Form** and submit your request. An application packet will be mailed to you upon receipt of your request.

Upon receiving an approval letter, the applicant will need to:

- make an appointment with a registered Test Center to take the exam
- pay a nominal fee to the Test Center

Retesting by CBT after failing a written test is allowed, so long as your application is in an approved status.

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Registered Computer-Based Testing Centers

Contact each testing location to schedule a CBT exam.

City	Test Center	Location	Contact Information
Amarillo	Amarillo College	Student Service Center, 101 2201 South Washington Amarillo, Texas	Website: **Amarillo Testing Center** Email: **acproctor@actx.edu** Phone: 806-371-5445
Arlington	North Central Texas Council of Governments	Classroom A 624 Six Flags Drive, Ste 125	Website: **NCTCOG Testing Center** Email: **NCTCOGTraining@nctcog.org** Phone: 817-608-2310
Austin	Austin Community College	Visit the ACC website to view testing locations	Website: **ACC Testing Center** Email: **bact@austincc.edu** Phone: 512-223-7395
Brownsville	The University of Texas at Brownsville	UTB Office of Testing 1601 E. Price Rd,Ste. E Brownsville, TX 78520	Website: **UTB Testing Center** Email: **testing@utb.edu** Phone: 956-882-7084
Bryan	Texas A & M Engineering Extension Service	TAMU Riverside Campus, Bldg 8004 3100 State Hwy 47 Bryan, TX 77807	Website: Email: Phone: 800-723-3811
Fort Worth	Tarrant County College	Northwest Campus WCTS-1133 4801 Marine Creek Pkwy Fort Worth, TX 76179	Website: **TCC Testing Center** Email: **ProfessionalTesting@tccd.edu** Phone: 817-515-7653
Galveston	Galveston College	4015 Avenue Q Galveston, TX 77550	Website: **GC Testing Center** Email: **mmackey@gc.edu** Phone: 409-944-1290
Houston	Houston Community College	1300 B Holman St, RM 211 Houston, TX 77004	Website: **HCC Testing Center** Email: **ce.testing@hccs.edu** Phone: 713-718-6012
Houston	Texas Southern University	Roderick Paige Building Basement Level, RM 007 3100 Cleburne St Houston, TX 77004	Website: **TSU Testing Center** Email: **testing@tsu.edu** Phone: 713-313-7387
Huntsville	Sam Houston State University	Huntsville Campus 1921 Avenue J Academic Building IV, RM 102 Huntsville, TX 77340	Website: **SHU Testing Center** **Huntsville Testing Center** Email: **test.ctr@shsu.edu** Phone: 936-294-1025

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Killeen	Central Texas College	6200 W Central Texas Expressway Killeen, TX 76549	Website: College of Mainland Testing Center Email: joanna.johnson@ctcd.edu Phone: 254-526-1520
Nacogdoches	Stephen F. Austin University	Rusk Bldg, RM 328 1936 North St Nacogdoches, TX 75962	Website: SFA Testing Center Email: sfatesting@sfasu.edu Phone: 936-468-3958
San Antonio	Alamo Colleges – San Antonio College	San Antonio College Assessment / Testing Center Fletcher Administrative Center Bldg. #112 (FAC #112) 1819 N. Main Ave San Antonio, TX 78212	Download Additional Information for Registration (PDF): http://www.alamo.edu/WorkArea/DownloadAsset.aspx?id=51227 Contact: Oscar C. San Miguel Email: osan@alamo.edu Phone: 210-486-0446
Texarkana	Texarkana College	Palmer Memorial Library 2500 North Robison Rd Texarkana, TX 75599	Website: TC Testing Center Email: texarkanacollege.edu/forms/email/ Phone: 903-823-3278
Texas City	College of the Mainland	Enrollment Center A-126 1200 Amburn Rd Texas City, TX 77591	Website: Central Texas Testing Center Email: testingcenter@com.edu Phone: 409-933-8676
The Woodlands	Sam Houston State University	The Woodlands Center 3380 College Park Dr. Ste. 303 The Woodlands, TX 77384	Website: SHU Testing Center The Woodlands Testing Center Email: test.ctr@shsu.edu Phone: 936-294-1025
Victoria	The University of Houston at Victoria	3007 N. Ben Wilson Victoria, TX 77901	Website: UHV Testing Center Email: testing@uhv.edu Phone: 361-570-4285
Weatherford	Weatherford College	Jack Knight Building 225 College Park Dr Weatherford, TX 76086	Website: Weatherford Testing Center Email: testing@wc.edu Phone: 817-598-6383
Wichita Falls	Midwestern State University	Hardin Admin. Bldg. RM 224 3410 Taft Blvd Wichita Falls, TX 76308	Website: MSU Testing Center Email: lynn.ducioame@mwsu.edu Phone: 940-397-4676

Keep checking this webpage for updates and additions to the list of registered CBT sites.

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Appendix D

Course Final Exam

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Instructional Guidance

Time

30 Minutes

Materials/Equipment

1. Course exam (Appendix D)
2. Pens or pencils for participants

Instructor Preparation

Instruct participants to turn to the course exam in the participant manual (Appendix D). Hand out other necessities, and instruct participants to prepare open book materials (if applicable). Discuss the time limit of 30 minutes to complete the exam. Answer preliminary questions. Begin the exam.

Upon class completion of the exam, review answers to exam questions. Answer any additional questions the participants may have.

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1. In Texas, water operator licensing is administered by the _____.

   a. EPA

   b. TEEX

   c. **TCEQ**

   d. OSHA

2. Which minerals cause hardness in water?

   a. calcium and manganese

   b. nitrates and phosphates

   c. **magnesium and calcium**

   d. iron and magnesium

3. The most important federal law impacting the water utility industry is the _____.

   a. Water Resources Development Act

   b. Hazard Communication Act

   c. Federal Water Pollution Control Act

   d. **Safe Drinking Water Act**

4. The four water quality standards established for drinking water in the Safe Drinking Water Act are chemical, bacteriological, radiological, and _____.

   a. mineral

   b. **physical**

   c. thermal

   d. taste and odor

   e. organic/inorganic

5. The minimum allowable pressure in the distribution system under emergency conditions is _____.

   a. 35 psi

   b. **20 psi**

   c. 30 psi

   d. none listed

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6. Water vapor given off by plants and trees is known as _____.

   a. precipitation

   b. transportation

   c. evaporation

   d. **transpiration**

7. Organic matter includes _____.

   a. leaves, beavers, birds, clay

   b. wood, fish, algae, sand

   c. **wood, dogs, algae, and bacteria**

   d. plants, animals, humans, minerals

8. The single most important water treatment process is _____:

   a. coagulation, sedimentation, and filtration

   b. taste and odor removal

   c. **disinfection**

   d. fluoridation

9. Excessive nitrates in drinking water can cause _____ syndrome in infants.

   a. bad baby

   b. bloody baby

   c. blue body

   d. **blue baby**

10. A sanitary control easement must cover land within _____ feet of a public water well.

    a. 50

    b. **150**

    c. 500

    d. 100

11. A sample for physical and chemical analysis of a new well must be taken after _____ hours of continuous pumping.

    a. 24

    b. **36**

    c. 20

    d. 30

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12. Chapter 290 Rules and Regulations requires chemical analysis of surface water supplies every _____.

    a. three years

    b. six months

    c. **year**

    d. both a and c

13. Detention time in sedimentation basins must be at least _____ hours to allow floc to settle.

    a. **6**

    b. 4

    c. 5

    d. 3

14. Backwashing should expand the filter media by _____ percent.

    a. 30 to 60

    b. 25 to 30

    c. 15 to 20

    d. **30 to 50**

15. In Texas, all public water systems are required to have _____ facilities.

    a. ozonation

    b. softening

    c. **chlorination**

    d. trihalomethane

16. The MCL for Trihalomethanes in drinking water is _____.

    a. 0.060 mg/L

    b. 0.6 mg/L

    c. **0.080 mg/L**

    d. 0.8 mg/L

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17. At room temperature chlorine gas is greenish-yellow, has a pungent odor, is _____ times heavier than air.

    a. 2

    b. **2 1/2**

    c. 1 1/2

    d. 3

18. Diseases that may be spread by inadequately disinfected water are _____.

    a. typhoid, cholera, dysentery, flu

    b. hepatitis A, polio, gastroenteritis, measles

    c. **typhoid, cholera, infectious hepatitis, legionnaires disease**

    d. dysentery, cholera, cancer, polio

    e. all the above

19. Minimum chlorine residuals of _____ (free) and _____ (combined) are required in the far reaches of the distribution system.

    a. .5/0.2

    b. 2/5

    c. 5/2

    d. **0.2/0.5**

20. Parameters that affect coagulation are _____.

    a. turbidity

    b. pH and alkalinity

    c. coagulant and dosage

    d. **all the above**

    e. none of the above

21. Do not work in a trench _____ feet or deeper unless it is protected from cave-in.

    a. 7

    b. **5**

    c. 6

    d. 3

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22. Place spoil banks at least_____ feet from the edge of the excavation.

    a. 4

    b. **2**

    c. 3

    d. 1

23. Dose new water mains with a minimum _____mg/L or more of chlorine at least every _____ hours.

    a. **25/24**

    b. 500/24

    c. 50/6

    d. 200/1

24. One bacteriological sample is required for each _____ of new completed main.

    a. 10,000 feet

    b. mile

    c. 1,000 yards

    d. **1,000 feet**

25. A cross connection is a physical connection between a public water supply and 1) another supply of unknown or questionable quality, 2) any source that may contain contamination, 3) any water _____.

    a. safe to drink

    b. treated to a greater degree

    c. treated to potable quality

    d. **treated to a lesser degree**

26. Maximum spacing between ladders in a trench is _____.

    a. 25 feet

    b. **50 feet**

    c. 75 feet

    d. there is no such requirement

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27. When should a rapid sand filter be backwashed?

    a. when it gets dirty

    b. when water will no longer pass through the filter

    c. loss of head of 6 to 10 feet

    d. turbidity readings higher than 0.5 NTU

    e. **all listed**

28. A ditch 4 feet wide, 6 feet deep, and 1,000 feet long will be excavated. How many cubic yards of pipe bedding will be needed to bed the trench 7 inches deep?

$$\frac{4 \times 1{,}000 \times 0.58}{27} = 85.9$$

    a. **86**

    b. 2,320

    c. 23,200

    d. 860

29. How many gallons will 5,000 feet of 18-inch water pipe hold?

$$3.14 \times 0.75 \times 0.75 \times 5{,}000 \times 7.48 = 66{,}057.75$$

$$18^2 \times 0.0408 \times 5{,}000 = 66{,}096$$

    a. 41,600 gallons

    b. 58,500 gallons

    c. 62,000 gallons

    d. **66,100 gallons**

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30. A tank that has a capacity of 700,000 gallons must be disinfected with a dosage of 50 mg/L of chlorine. How much 65% HTH will it take to achieve the same goal?

$$\frac{0.7 \times 8.34 \times 50}{0.65} = 449.07$$

a. 292 pounds

b. 356 pounds

c. **449 pounds**

d. 552 pounds

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